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TRACKING & COMMUNICATIONS DEVELOPMENT DIVISION

JSC INTERNAL NOTE

VOLUME I, ASCENT

SHUTTLE STS-2 MISSION COMMUNICATION SYSTEMS RF COVERAGE AND PERFORMANCE PREDICTIONS

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SHUTTLE STS-2 MISSION COMMUNICATIONS SYSTEMS
RF COVERAGE AND PERFORMANCE PREDICTIONS

VOLUME I - ASCENT

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PREFACE

Radio Frequency (RF) coverage analysis has always been and remains an important part of the communication system analysis performed for NASA manned space flight programs. It uses the specified or measured performance of the communication and tracking equipment, ground-test-range-measured spacecraft antenna patterns, mission trajectories, ground station locations, and ground station performance characteristics to generate communication system dynamic performance predictions versus mission time for all phases of a mission. The analysis identifies the periods when the various RF links will provide good communications as well as when they may not, such as during periods of vehicle, terrain, or Solid Rocket Booster (SRB)-exhaust-plume blockage. During the early planning stage of a mission, RF coverage results provide feedback for mission planning and support personnel to identify RF coverage problem areas and to help optimize resources and support activities. Not infrequently, such feedback results in some redesign or reconfiguration of the system or mission plan. This process often goes through several reiterations before a final mission plan is generated.

When a final operational trajectory is produced and analyzed for RF coverage, a formal document detailing the communication available as a function of mission elapsed time is published; it provides signal-strength graphs, antenna selections, and other operational aids. For Space Transportation System-2 (STS-2, the second orbital mission of the Space Shuttle), this data is being published in three volumes: Volume I - Ascent; Volume II - Descent; and Volume III - Onorbit. This is Volume I.

After a mission is completed, flight recorded data is available on the actual performance of the communication system; this data and actual mission trajectory and attitude data are processed and compared with the predictions generated prior to the mission. Any anomalies are resolved, and the performance of the system is then assessed and deficiencies corrected or workarounds implemented. This process continues, mission after mission.

In preparation of this document, data from various organizations within the Johnson Space Center (JSC) and other NASA centers is required. This includes trajectory data from the Mission Planning and Analysis Division/JSC, measured and theoretical antenna data from the antenna test range of the Tracking and Communications Development Division/JSC, ground station characteristics from the Goddard Space Flight Center (GSFC), the United States Air Force, Federal Aviation Agency, and Electromagnetic Compatibility Analysis Center (ECAC), and engineering data on the communications equipment from the various program contractors. Additional support, postflight, for data and data processing is provided by GSFC (Spaceflight Tracking and Data network ground stations), JSC elements within the Engineering and Development Directorate, the Flight Operations Directorate, the Data Systems and Analysis Directorate, and the Integration Division of the Program Operations Office.

Acronyms appear frequently in the report and the more familiar ones are not defined in the text because of the disruptive effect to the reader of excessive parentheticals; they are instead collected and defined by a list of acronyms and abbreviations immediately following.

ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFSCF	Air Force Satellite Control Facility (An Air Force ground station)
AGC	Automatic Gain Control
AM	Amplitude Modulation
AOA	Abort Once Around
AOS	Acquisition of Signal
ATO	Abort to Orbit
BC	Bottom Center
BIϕ-L	Biphase-Level
BL	Bottom Left
BR	Bottom Right
DFI	Developmental Flight Instrumentation
DOD	Department of Defense
ECAC	Electromagnetic Compatibility Analysis Center
EIRP	Effective Isotropic Radiated Power
ET-SEP	External Tank Separation
ET	External Tank
FAA	Federal Aviation Agency
FDM	Frequency Division Multiplexed
FM	Frequency Modulation
GET	Ground Elapsed Time
GMT	Greenwich Mean Time
GPC	General Purpose Computer

GRTLS	Glide/Return-to-Launch Site
GSFC	Goddard Space Flight Center
GSTDN	Ground/Spaceflight-Tracking-and-Data Network
G/T	Antenna Gain/System Noise Temperature
GRARE	Ground Receiving and Ranging Equipment
HDR	High Data Rate
IRIG	Inter-Range Instrumentation Group
JSC	Johnson Space Center
kbps	kilobits per second
kft	kilo feet
KSC	Kennedy Space Center
LDR	Low Data Rate
LNA	Low Noise Amplifier
LOS	Loss of Signal
ME	Main Engine
MECO	Main Engine Cutoff
MFR	Multifunction Receiver
MSBLS	Microwave Scanning Beam Landing System
NASA	National Aeronautics and Space Administration
NAV	Navigation
NRZ-L	Nonreturn to Zero Level
OI	Operational Instrumentation
OMS	Orbital Maneuvering System
PCM	Pulse Code Modulation
PM	Phase Modulation
P_{rec}/N_0	Ratio of signal power (P_{rec}) to noise spectral density (N_o)
PSK	Phase-Shift-Keying

RHC	Right-Hand Circular
RF	Radio Frequency
RTLS	Return to Launch Site
SGLS	Space Ground Link System
SRB	Solid Rocket Booster
SRB-SEP	Solid Rocket Booster Separation
SSO	Space Shuttle Orbiter
SSPO	Space Shuttle Program Office
STDN	Spaceflight Tracking and Data Network
STS-1	Space Transportation System-1
STS-2	Space Transportation System-2
TACAN	Tactical Air Navigation
TL	Top Left
TC	Top Center
TDM	Time Division Multiplexed
TDRSS	Tracking and Data Relay Satellite System
TPS	Thermal Protection System
TR	Top Right
TRP	Total Received Signal Power
TV	Television
USAF	United States Air Force
WI	Word Intelligibility

Ground Stations:

ACN	Ascension
AGO	Santiago

BDA	Bermuda
BUC	Buckhorn
DFRC	Dryden Flight Research Center
ETC	Engineering Test Center (Greenbelt, Md.)
GBI	Grand Bahama
GDS	Goldstone
GWM	Guam
HAW	Hawaii
IOS	Indian Ocean Station (AFSCF ground station)
MAD	Madrid
MIL	Merritt Island
ORR	Orroral
PDL	Ponce de Leon
QUI	Quito
TUL	Tula Peak
VAN	Vanguard

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1. INTRODUCTION

1.1 Purpose and Scope

The RF communications capabilities and nominally expected performance for the Shuttle STS-2 mission, the second orbital flight of the Shuttle, is provided by this report. This volume, volume I, covers ascent (including RTLS abort); volume II will address descent; and volume III, onorbit. Results are based on the latest available reference trajectory*, STS-2 revised Cycle 2 (ref. 1), for a launch date of October 9, 1981, with nominal lift-off at 1200 GMT (0700 Eastern Standard time) from pad 39A at KSC. The launch azimuth is 63°, the final orbital altitude is 150 nmi, the inclination is 38°, and landing is at Edwards AFB in California on runway 23, approximately 124 hr 10 min later.

Predicted performance is given mainly in the form of plots of signal strength versus elapsed mission time for the STDN (downlink) and Shuttle Orbiter (uplink) receivers for the S-band PM and FM, and UHF systems. Performance of the NAV and landing RF systems is treated in this volume for RTLS abort, since in this case the spacecraft will loop around and return to the launch site. NAV and landing RF systems include TACAN, MSBLS, and C-band altimeter. Signal strength plots were produced by a computer program which combines the spacecraft trajectory, antenna patterns, transmit and receive performance characteristics, and system mathematical models. When available, measured spacecraft parameters were used in the predictions; otherwise, specified values were used. Specified ground station parameter values were also used. Thresholds and other criteria on the graphs are explained in section 1.6.

*Some parts of the trajectory are actually earlier versions of Cycle 2 which, because they did not change (or changed so minutely), were used instead. In the revised Cycle 2 trajectories "lofting" is included in the first stages of ascent. The resultant effect on the look angle vector should be small (<5°). (If the launch date slips, in general the data in this report will still be typical for small trajectory/attitude changes (<5°) but could be significantly different for large changes (particularly for 10° or more). At the time of writing this report, the launch date is being slipped, and will probably be 3-5 weeks later. Trajectory personnel have indicated that trajectory and attitude changes will likely be small enough to have little effect on the results given in this report.

Volume I is arranged in six major sections. Section 1 provides general introductory information on vehicle and antennas, a brief description of the planned, or nominal trajectory, and some general introductory information on the form of the results. Section 2 describes ascent in more detail and discusses ground station coverage. Section 3 provides the performance prediction data for nominal ascent and section 4 provides data for the abort cases--RTLS and AOA. Sections 5 and 6 provide a brief summary description of communication modes, functions, capabilities, requirements, and characteristics for S-band and UHF, respectively.

1.2 Shuttle Vehicle/Antenna Configuration

The Shuttle is configured at lift-off as shown in figure 1-1, consisting of the Orbiter, two Solid Rocket Boosters (SRBs), and the External Tank (ET). Locations of the various Shuttle antennas are indicated on this figure. The Orbiter has four omni-type antennas, "quads," for the primary S-band communications and tracking functions on the PM link, and two omni-type "hemi" antennas for the S-band FM link (a downlink only), which provides main engine data and DFI data during ascent. An omni-type UHF antenna is provided for a backup voice link. Three pairs of TACAN antennas (L-band) provide descent navigation support beginning, for RTLS, at an altitude of 200 kft or more. Three Ku-band Microwave Scanning Beam Landing System (MSBLS) antennas provide landing area navigation support beginning at about 15 kft. Four C-band altimeter antennas provide altitude data beginning around 500 ft. In addition, the ET and each SRB has a pair of range-safety antennas. (The range safety links are not treated in this report, but these links have more than adequate margins.) The spacecraft will be tracked by ground-based C-band skin-track radars during all mission phases.

The primary link, or operations link, is the S-band PM link via the quad antennas, and this report is primarily concerned with this link. The S-band FM link and the UHF backup-voice link are treated only briefly, as their requirements are secondary to the PM operations link and since some of the PM link analysis (geometry, look angles, etc.) applies to these links. TACAN, and MSBLS, links are treated only under the section dealing with RTLS. The

altimeter, which has adequate margin at altitudes up to about 5 kft, is to be used only during the last 500 ft.

1.3 Shuttle Antenna Switching

As noted above, the Shuttle has four S-band quad antennas, one for each quadrant about the spacecraft. Normally, antenna switching is automatic and is performed by the GPC, though manual switching is also available. The automatic switching is based solely on geometry, with switching occurring when the look angle to the ground station crosses from one quadrant to another. It does not occur exactly at the boundary since 2° of hysteresis is built in to avoid oscillatory back-and-forth switching that otherwise could occur if the line-of-sight should hover around a quadrant boundary. (Example: Let 0° to 90° represent one quadrant and 90° to 180° an adjacent quadrant, and assume the line-of-sight to the ground station has moved from 86° to 94° and then back from 94° to 86°. Because of the 2° hysteresis, antenna switching would occur at 92° ascending and 88° descending, instead of 90° in both cases.)

Switching for the Shuttle's two S-band FM hemi antennas is similar. It is automatic when the quads are automatic and is manual when the quads are manual. One hemi covers the upper hemisphere, and one the lower. The boundary between these two hemispheres coincides with the boundary between the upper pair of quads and the lower pair of quads, so that one switching function operates both the hemis and the quads along this hemispherical boundary (hence the hemis also have 2° of hysteresis). Of course, between the upper left and right quadrants, and lower left and right quadrants, the switching function only involves the quads.

The UHF system has one antenna (bottom) and no switching is involved.

TACAN antenna switching is not geometrical but is based on an absence-of-signal time interval of 10 sec. There are six TACAN antennas, three upper and three lower. The top left (TL) is switch-paired with the bottom left (BL), top center (TC) with the bottom right (BR), and the top right (TR) with the bottom center (BC). These pairings are fixed; for example, the TL can switch

only to the BL, and vice-versa. Thus when the TACAN system is ON, three antennas are ON, three are OFF; of course, only one at a time within each pairing can be ON. All three top antennas may be ON simultaneously, all three bottom, two top and one bottom, or one top and two bottom. In the absence of a signal, an antenna will switch to its conjugate after 10 sec. If no signal is acquired by the conjugate after 10 sec, it will switch back, etc.

The orbiter MSBLS has three fully redundant strings, i.e., the three Ku-band antennas connect separately to three transponders. The radar altimeter has two redundant strings and each transponder connects to two antennas, one for transmit and one for receive. When the MSBLS system or the altimeter systems is ON, data from all strings is being processed. Redundancy management software will be used to detect failure and determine the validity of the data.

1.4 Spacecraft Antenna Patterns

The antenna gain patterns used in preparing this report were measured on Shuttle mockups at the test facilities of the Tracking and Communications Development Division, JSC. Patterns for the Orbiter/SRB/ET (lift-off to SRB-SEP), the Orbiter/ET (SRB-SEP to ET-SEP), and the Orbiter-only (post-ET-SEP, onorbit, and descent) configurations were taken on a 1/10-scale, full-vehicle, mockup; full-scale patterns were also taken for the orbiter-only case but with a ground plane (contoured 10 to 20 ft section of the vehicle skin in the vicinity of the antenna) rather than the entire Orbiter. Even though the JSC test facility is excellent, both the 1/10-scale and full-scale patterns have some inherent limitations which could affect the fidelity of these measured patterns, especially in antenna off-axis lower-gain regions and in regions of rapidly varying antenna gain. The 1/10-scale patterns, for example, by definition require vehicle and antenna scaling -- thus the antenna used is a scaled simulation of the actual, as is the vehicle -- and such scaling is always subject to practical limitations. There are, for example, the problems of scaling the electrical characteristics of the Shuttle Thermal Protection System (TPS) tiles. And the full-scale patterns, as they are taken on the aforementioned ground plane, do not reflect possible effects of spacecraft

appendages such as the wings, the tail, etc. Both sets of patterns, of course, are subject to possible fidelity limitations as a result of the inherent differences between any ground test range and a free-space flight environment. Consequently, the signal strength curves cannot be expected to exactly track the actual, but rather should be considered as representative. Moreover, even minor deviations of the actual trajectory and attitude timeline from the reference one used in generating this report can result in large differences in signal strength at any single instance of time. For example, a few degrees difference in the Shuttle-to-ground-station look angle can, in some small regions of an antenna pattern, amount to 10 to 20 dB difference in antenna gain and hence 10 to 20 dB difference in signal strength.

The 1/10-scale antenna pattern data, rather than the full-scale data, was used for the RF link predictions given by this report because (1) the full-scale data was taken on a ground plane, not the Shuttle spacecraft (understandably so because of the problems associated with the sheer size of a full-scale spacecraft), whereas the 1/10 scale data employed a mockup of the entire vehicle (1/10 scale), and (2) the 1/10-scale data was taken for the Orbiter/ET/SRB configuration (lift-off to SRB-SEP), the Orbiter/ET configuration (SRB-SEP to ET-SEP), and the Orbiter-only configuration (the remainder of the mission).

1.5 S-band and UHF Ground Station Antennas, Receivers, and Transmitters

The S-band antenna systems (ref. 2) used by the GSTDN stations for operation with the Shuttle are listed in table 1-I. The S-band receiver used by the ground stations is the Multifunction Receiver (MFR), which has a noise figure of approximately 8 dB. Between the antenna system and the MFR receiver, the GSTDN stations use a Low Noise Parametric Amplifier (LNA); the combined noise figure is 1 dB. Ground stations BUC, PDL, and TUL are exceptions, and use an uncooled paramp; the combined noise figure is 3 dB. Receiving G/T values are included in table 1-I and are based on an antenna elevation of 3°.

Transmitting EIRPs and transmitter power are given in table 1-II. (GBI is not included as it does not have uplink capability)

Table 1-III lists the analogous information for the UHF ground station antennas and receivers. The UHF receivers have a noise figure of 3 to 4 dB (3.2 dB is assumed for this report) except for DFRC which is 12 dB. The UHF G/Ts are listed in table 1-III and are based on an antenna elevation of 3°, the same as the S-band G/Ts. Transmitting EIRPs and transmitter power for UHF are given in table 1-IV.

Ground station antenna keyholes (S-band only) and terrain blockage of the antenna field-of-view are combined and denoted by shading on the signal-strength plots.

One USAF SCF ground station, IOS, is participating in the STS-2 support. The IOS/AFSCF station will have the capability to support the S-band PM link, S-band OI and DFI FM links, and the UHF voice link. IOS has an 18.3 m (60 ft) antenna and uses a Ground Receiving and Ranging Equipment (GRARE) receiving system for S-band. For UHF, IOS uses a Teltrac 18 antenna and transceiver supplied by GSFC.

1.6 Explanation of Graphs and Graph Labeling

Total received signal power (TRP) is graphed from horizon to horizon for ground station passes, i.e., curves begin and end at ground station 0° elevation points. Thresholds (i.e., the required signal levels, the 0-dB circuit margin points), ground station antenna keyhole and terrain blockage, times of major events, and 5° ground station elevation are indicated on the plots.

Times of major events are denoted on the graphs by acronyms or abbreviations, such as SRB-SEP for solid rocket booster separation and ET-SEP for external tank separation. The 5° elevation points, i.e., when the spacecraft is 5° in elevation from the ground station, both ascending and descending, are denoted by vertical dashed lines labeled 5° EL.

The UHF voice threshold is defined as the value of total received power that will produce the required postdetection signal-to-noise ratio for 90-percent

Word Intelligibility (WI). The 90-percent WI voice threshold is indicated on the signal strength graphs as a dash-line; the 70-percent level (not indicated on the graph) is about 12 dB less than the 90-percent level. The S-band PM uplink data threshold is defined as the value of Shuttle total received power corresponding to a bit error probability of 10^{-4} or less, or a command rejection probability of 1.26×10^{-2} or less. The downlink telemetry threshold is defined as the value of total received power which will produce a bit error probability of 10^{-4} at the bit synchronizer output. The S-band PM-link threshold values (ref. 3) depend on the configuration of the Orbiter S-band PM system, i.e., high or low power mode, high or low data rate, and whether ranging is ON or OFF. For STS-2 ascent, high-power/high-data-rate/ranging ON is planned, and the thresholds on the graphs are based on this configuration. MIL is to employ the high-power 10-kW transmit-power mode. The S-band FM-link threshold is defined as the value of Shuttle total received power corresponding to a 10 dB IF signal-to-noise ratio. The data thresholds are indicated on the graphs by horizontal dashed lines and labeled "0 dB Margin". Thresholds for ranging, carrier acquisition, etc., are listed in table 1-V. (The PM thresholds in table 1-V and on the graphs for ascent are applicable to the new ascent-phase acquisition mode which has just recently been defined and is to be added to reference 3.)

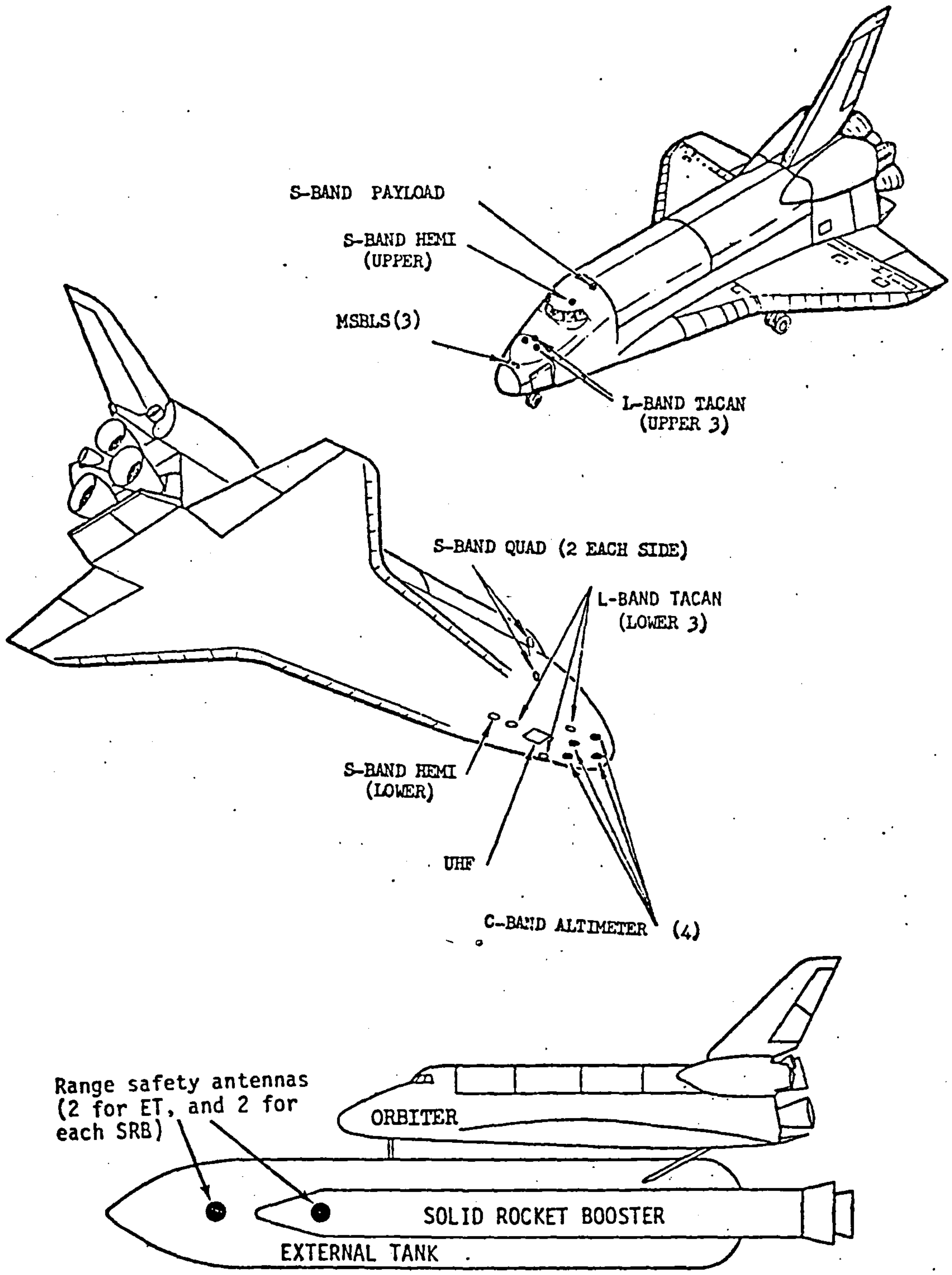


Figure 1-1.- Shuttle configuration; antenna locations.

TABLE 1-I.- S-BAND GROUND STATION ANTENNAS AND G/Ts

Antenna[a] size	Effective receive antenna gain (dB)	Preamp	Min. G/T (dB/K)	Stations
26 m (85 ft)	53.2	LNA	31.2	GDS, MAD
12 m (40 ft)[b]	44.9	LNA	21.2	QUI
9 m (30 ft)	43.5	LNA	22.0	ACN, AGO, BDA, ETC, GDS, GWM, HAW, MAD, MIL, ORR
9 m (30 ft)	42.0[c]			GBI
4.3 m (14 ft)	36.0	Uncooled paramp	9.9	QUI
4.3 m (14 ft)	36.8	Uncooled paramp	9.8	BUC, PDL, TUL
18.3 m (60 ft)	48.2	Uncooled paramp	22.9	IOS/AFSCF

[a]RHC polarization

[b]For downlink only (the 14-ft antenna in line 5 is used for transmitting)

[c]Estimate

TABLE 1-II.- S-BAND GROUND STATION TRANSMITTING EIRPs AND TRANSMIT POWER

Antenna[a] size	Effective transmit antenna gain (dB)	Transmit power (dBw)	EIRP (dBw)	Stations
26 m (85 ft)	50.5	33	83.5	GDS,MAD
9 m (30 ft)	43.0	33[b]	76.0[b]	ACN, AGO, BDA, ETC, GDS, GWM, HAW, MAD, MIL, ORR
4.3 m (14 ft)	35.8	33	68.8	QUI
4.3 m (14 ft)	34.0	23	57.0	BUC, PDL, TUL
18.3 m (60 ft)	42.7	30	72.7	IOS

[a]RHC polarization

[b]For MIL ascent support, the transmit power is 40 dBw (10 kw) and the EIRP is 83 dBw.

TABLE 1-III.- UHF GROUND STATION ANTENNAS AND G/Ts

Antenna[a]	Effective receive antenna gain (dB)	Preamp	Min. G/T (dB/K)	Stations
Teltrac 18	18.5	Yes	-8.3	GDS, HAW, MAD, MIL[b], TUL, IOS
Teltrac 32	21.0	Yes	-5.6	GWM
Quad helix (8417 mount)	17.5	Yes	-9.3	BDA
Discone (omni)	0.9	No	-33.2	DFRC
3.7 m (12 ft)	12.5	No	-18.7	DFRC

[a]Linear polarization

[b]MIL also has the UHF discone (omni) antenna; this second UHF system has no preamp and G/T = -31.4 dB/K

TABLE 1-IV.- UHF GROUND STATION TRANSMITTING EIRPs AND TRANSMIT POWER

Antenna[a]	Effective transmit antenna gain (dB)	Transmit power (dBw)	EIRP (dBw)	Stations
Teltrac 18	16.4	20	36.4	GDS, HAW, MAD, MIL[b], TUL, IOS
Teltrac 32	18.2	20	38.2	GWM
Quad helix (8417 mount)	15.4	20	35.4	BDA
Discone (omni)	-1.3	20	18.7	DFRC
3.7 m (12 ft)	12.5	20	32.5	DFRC

[a]Linear polarization

[b]MIL also has the UHF discone (omni) antenna; this second UHF system has an EIRP of 20.9 dBw

TABLE I-V.- S-BAND THRESHOLDS (0-dB CIRCUIT MARGIN LEVELS);
PM UPLINK AND DOWNLINK, FM DOWNLINK

Link	Mode	Channel	Data threshold[a] (dBm)	In-lock tracking threshold (dBm)	Acquisition threshold (dBm)
(a) Ground Stations - SSO S-band PM uplink (Ascent phase)					
PDL	HDR, encoded, without ranging	72 kbps	-117.8	-122.8	-121.6/-122.2[b]
		Two-way Doppler	-122.8		
MIL BDA	HDR, encoded, with ranging	72 kbps	-115.2	-118.6	-117.0/-116.6[b]
		Ranging	-118.6		
		Two-way Doppler	-118.6		
GBI	HDR, encoded without ranging	72 kbps	-106.8[d]		
MAD	HDR, with ranging	72 kbps	-110.5	-122.4	-126.8/-122.1[c]
		Ranging	-122.4		
		Two-way Doppler	-122.4		
IOS	HDR SGLS PSK	72 kbps	-106.4	-117.0	-121.1/-117.0[c]
		Two-way Doppler	-117.0		
(b) SSO - Ground Stations S-band PM downlink (Ascent phase)					
PDL	High power, HDR without ranging	192 kbps	-100.9	-118.1	-108.1
		Two-way Doppler	-119.0		
MIL BDA MAD	High power, HDR with ranging	192 kbps	-106.4	-123.6	-113.6
		Ranging	-123.6		
		Two-way Doppler	-123.6		
IOS	Low power, HDR SGLS PSK	192 kbps	-101.4	-126.0	-122.7
		Two-way Doppler	-126.0		
(c) SSO - Ground Station S-band FM downlink					
MIL BDA	ME data	60 kbps	-99.8	NA	NA
MAD	OI playback	1024 kbps	-99.6	NA	NA
IOS	OI playback	1024 kbps	-95.8	NA	NA
PDL	DFI data	128 kbps	-94.3	NA	NA
MIL BDA MAD	DFI data	128 kbps	-99.8	NA	NA
IOS	DFI data	128 kbps	-98.4	NA	NA

[a]Doppler and ranging thresholds are constrained by in-lock tracking threshold.

[b]The first value is for automatic acquisition; the second value is for carrier-only acquisition and maintain in-lock once the data modulation is switched on.

[c]The first value is sufficient to acquire carrier-only but would not sustain data modulation; the second value is the level required to maintain lock once data modulation is switched on.

[d]Estimate.

2. ASCENT DESCRIPTION AND GROUND STATION COVERAGE

The Shuttle orientation on the launch pad is such that the Orbiter tail fin (vertical stabilizer) points due south. Immediately after lift-off and tower clearance, a roll maneuver aligns the vertical stabilizer with the launch-azimuth plane, such that the Orbiter is in a heads-down orientation as it begins to pitch downrange in preparation for insertion into earth orbit.

The Shuttle launch and ascent scenario, including approximate geometrical coverage from MIL, GBI, and BDA, is illustrated simplistically in figure 2-1. The SRBs fire from lift-off until approximately 127 sec (corresponding to an altitude of about 26 nmi, and nearly 24 nmi downrange from MIL). After SRB separation, the Orbiter and ET remain mated until approximately 520 sec, which corresponds to an altitude of about 60 nmi and a downrange distance of about 650 nmi. Final orbital altitude for STS-2 is 150 nmi.

At lift-off, the Shuttle S-band PM communication link will be with MIL, the STDN ground station located about 8 nmi southwest of the launch pad. However, at about 45 sec GET, this link will be handed over to PDL to avoid the SRB plume blockage problem. Shortly after SRB-SEP (127 sec GET) it will be handed back to MIL (at about 145 sec GET). This PM link is the primary, or operations link; it provides voice, telemetry, ranging, and command.

For this link, the Shuttle uses the the quad antenna system which consists of four antennas approximately perpendicular to and nearly equally spaced about the vehicle X-axis (roll axis; see figure 2-1). The composite coverage of these four antennas at an antenna gain of +3dB is 40 to 50 percent of a sphere about the Orbiter. At a gain of +1dB, the coverage is about 80 percent, or just about all directions except small regions fore and aft. The Shuttle-to-ground-station look angle lies in the aft region during most of ascent but circuit margins with MIL are still more than adequate because the links are designed to operate at much greater ranges than those encountered. (Margins at MIL LOS, at about 8 min, are still greater than 20 dB and margins at this times for BDA are about 30 dB.) In the first 25 to 30 sec of ascent, the look angles to MIL and PDL are not in the aft region but vary rapidly from the

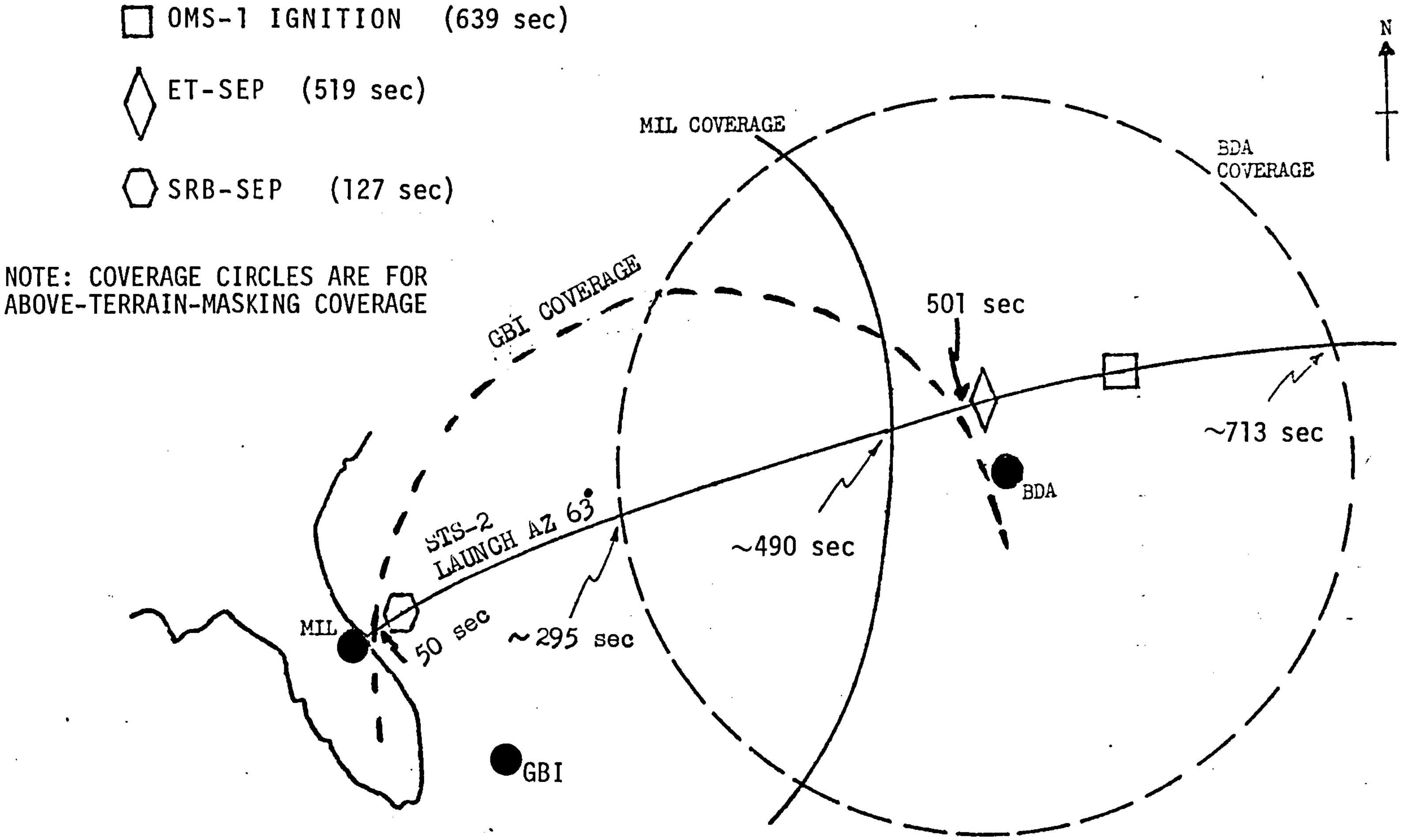
Shuttle upper left side down to the lower left side for MIL, and lower left to lower right for PDL, due to the vehicle roll maneuver just after lift-off.

Because of the accompanying change in quad antenna gain, signal strength on this link will undergo rapid and large fluctuations during this period, but circuit margins are still quite large, and the fluctuations are not expected to cause loss of lock.

An auxiliary data link, the S-band FM link (downlink only) via the hemi antennas, will provide main engine data and DFI data during ascent. (The FM link provides other services during onorbit -- TV, playback of recorded data, payload data.) A UHF voice link with MIL will also be operating during ascent.

The S-band ground-station network during the Apollo program included MIL, GBI, the launch-coverage ship VAN, and BDA, to provide communication with the vehicle during the ascent phase, from lift-off through earth-orbit insertion. VAN has since been closed down, and ascent coverage for the Shuttle program will be provided by MIL and BDA, with GBI providing receive-only capability for the S-band PM downlink. (Both BDA and GBI will be phased out when the TDRSS becomes operational. Moreover, BDA cannot cover the more northerly launches that are scheduled later in the program.) MIL will be assisted during the SRB exhaust-plume blockage period (from about 1 1/2 min to about 2 1/2 min after lift-off) by PDL, a mobile van S-band ground station located just north of the Cape so as to have a line-of-sight with the Shuttle outside the plume blockage region. The predicted plume blockage, which is a function of vehicle altitude, is indicated in figure 2-2. In this report, the plume size at 70 kft was used to calculate possible communication blockage. In STS-1, the PM link to MIL was blocked by the plume with resultant loss in data. The link to PDL was strong but showed occasional brief dropouts in data. In STS-1 during this period, the Shuttle optimum quad antenna selection was based on MIL; in STS-2 it will be based on PDL.

MIL has line-of-sight with the Shuttle from lift-off until about 8 min; BDA line-of-sight begins at about 4-1/2 to 5 min, so that ample overlap is available for handover from MIL.



Note: PDL coverage approximately same as MIL

Figure 2-1.- STS-2 nominal ascent and MIL, GBI and BDA coverage.

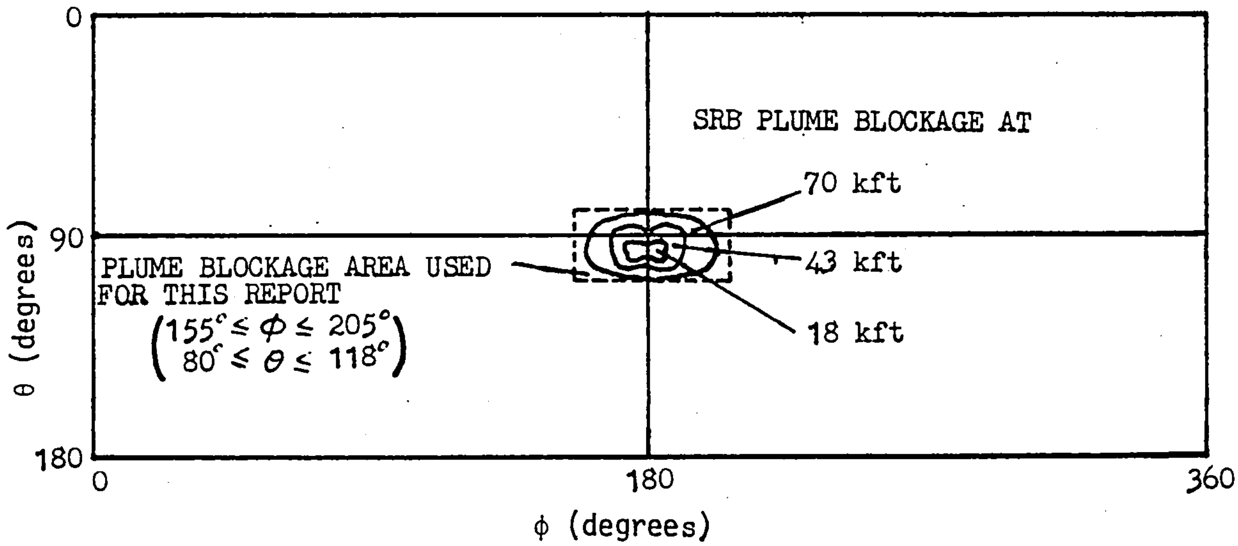


Figure 2-2.- Shuttle SRB-exhaust-plume blockage region.

3. RF COMMUNICATIONS PERFORMANCE PREDICTIONS FOR STS-2 ASCENT (NOMINAL)

Ascent, for the purposes of this report, is defined as the period from lift-off up to and including the OMS-1 burn. The data presented is generally extended beyond this so as to provide some overlap with the onorbit data to be published in volume III. In terms of ground station coverage, the data presented herein will include MIL (and PDL), GBI, BDA, MAD, and IOS passes. Table 3-I summarizes the type of communication links available at these stations.

At liftoff the Shuttle antenna selection will be based on MIL and MIL will also be utilized for both the uplink and downlink communications. Then, at about 12 sec after liftoff, the Shuttle attains line-of-sight with PDL and the Shuttle GPC will select the antenna most favorable for PDL. At about 45 sec, the plan is to handover the uplink from MIL to PDL and then hand back over to MIL at about 145 sec, after the plume blockage period (~85 sec to 135 sec). During this period the downlink can be selected from PDL, MIL, or GBI. From ~145 sec until handover to BDA, MIL will have the uplink, and the Shuttle antenna selection will also be based on MIL.

Figures 3-1 through 3-3 give plots of the predicted S-band PM, S-band FM, and UHF signal strength at MIL, PDL, GBI, and BDA from the Orbiter, from lift-off until ground station LOS, for the nominal STS-2 ascent. The FM system has two separate downlinks. They share the FM hemi antennas via a diplexer, one link at 2205 MHz (DFI data) and the other at 2250 MHz (OI data). The 2250-MHz link is plotted; the 2205-MHz link differs by a constant amount, which is indicated on the graphs. These are downlink graphs; figures 3-4 and 3-5 provide the corresponding graphs for the uplink from MIL, PDL, and BDA to the Orbiter (except for FM which is a downlink only). The S-band PM uplink is stronger than the S-band PM downlink because of the much greater transmit power on the ground, but there is little difference between UHF uplink and downlink. Figure 3-6 shows the one-way Doppler during ascent for MIL, PDL, GBI, and BDA for the S-band PM-link 2287.5-MHz frequency. Table 3-II lists the values of RF parameters such as transmit power, circuit loss, etc., used in producing the signal strength graphs. The 0-dB circuit-margin performance thresholds

are indicated on the graphs by horizontal dashed lines. The ascending and descending 5° elevation points (0° points are the beginning and end of each signal-strength curve), and SRB-SEP and ET-SEP, are also identified. The period when the line-of-sight with MIL passes through the SRB exhaust plume is indicated by the dotted field on the graphs. As noted previously, it is based on engineering estimates of the plume at about 70-kft altitude. The signal strength during this period will be much lower than shown because of plume attenuation, and will be erratic due to phase distortion by the plume, which causes S-band PM-link phase tracking loops to lose lock (even if the links do withstand the attenuation).

Results of SRB plume attenuation studies and postflight data analysis of STS-1 indicate that RF attenuation can reach a maximum of ~60 dB, depending on the geometry of the RF path and the SRB plume. The downlink to MIL would be lost with this amount of attenuation as is readily apparent by adjusting that portion of the graph downward by ~60 dB and noting that it is then below the dashed-line threshold. The MIL uplink, through considerably stronger, may be unusable because of severe phase distortion. Hence, for STS-2 the uplink will be via PDL from about 45 sec to 145 sec. The left-hand circular (LHC) polarization component from the PDL receiver will be terminated instead of combined with the right-hand circular (RHC) polarization signal, so as to avoid any multipath effect. Also, some modification to the frame-sync strategy will be implemented to make it more fault-tolerant.

The curves in figure 3-7 show the Orbiter line of sight to MIL, PDL, GBI, and BDA during STS-2 nominal ascent, plotted in ϕ, θ look-angle coordinates. The rectangular-box graph represents the total sphere of all possible directions looking outward from the Shuttle, with ϕ and θ defined by the insert in figure 3-8, $0 < \phi < 360°$, $0 < \theta < 180°$. (Note: This coordinate system is defined to be consistent with the one used in the antenna data given in this report and is not the standard IRIG coordinate system.). The graph is divided into four regions, corresponding to the four quadrants of a sphere. Each quadrant contains one of the four quad antennas (denoted UR for upper right, etc.) which are switched as explained in section 1.3. The predicted plume-blockage envelope is denoted by the inset dashed-line box. The fore and aft low-

antenna-gain regions of the quad antennas are indicated by the diamond-shaped regions in figure 3-8. SRB and ET shadowing or blockage regions are also shown. Antenna gain in the aft region ranges from about -10 dB to, in a few instances, as low as -40 dB; in the fore region, about -5 to -15 dB. The antenna patterns used for the signal-strength curves were measured with the vehicle (1/10 scale) present. The kidney-shape SRB blockage or shadowing in figure 3-5 is gone approximately 2 min after lift-off when SRB-SEP occurs. ET-SEP is approximately 8 1/2 min after lift-off, at which time the ET blockage is gone.

As the downlink signal-strength graphs show, the S-band PM link from the Orbiter to MIL has more than 30 dB margin (using the hi-power mode) when it enters the plume region, even though the look angles are in the aft region where antenna gain is generally low. The large margin is due to the close proximity of the spacecraft so shortly after lift-off. During the plume blockage period, however, signal degradation was large enough in STS-1 to cause the MIL-SSO uplink and downlink to both lose lock.

UHF voice in STS-1 during the plume blockage period was adequate though noisy. The UHF receivers are less sensitive to phase distortion and the lower UHF frequency is less attenuated by the plume -- the UHF plume attenuation is estimated to about 15 dB. Thus, plume attenuation may result in loss of the S-band links but the UHF link will likely provide usable voice communications.

As indicated on figure 3-1, GBI also has ample downlink S-band PM margin. However, GBI does not have transmit capability and its main use is to provide an alternate to PDL and MIL, as a source of downlink telemetry.

The first down-range station is BDA, whose coverage overlaps MIL's and extends on through ET-SEP and beyond. The combination of MIL, PDL, and BDA constitutes the continuous coverage available for STS-2 ascent communications. There is about 7 minutes from the end of BDA coverage until the beginning of the MAD pass, and then about 12 minutes from the end of MAD until the beginning of the IOS pass.

The data for MAD and IOS are given by figures 3-9 to 3-14. Signal strength curves (downlink and uplink) are in figures 3-9 to 3-12, Doppler plots in figure 3-13, and look-angle plots in figure 3-14.

Slant range from the Shuttle to ground stations is plotted in figure 3-15 for all of the ascent phase ground stations -- MIL, PDL, GBI, BDA, MAD, and IOS.

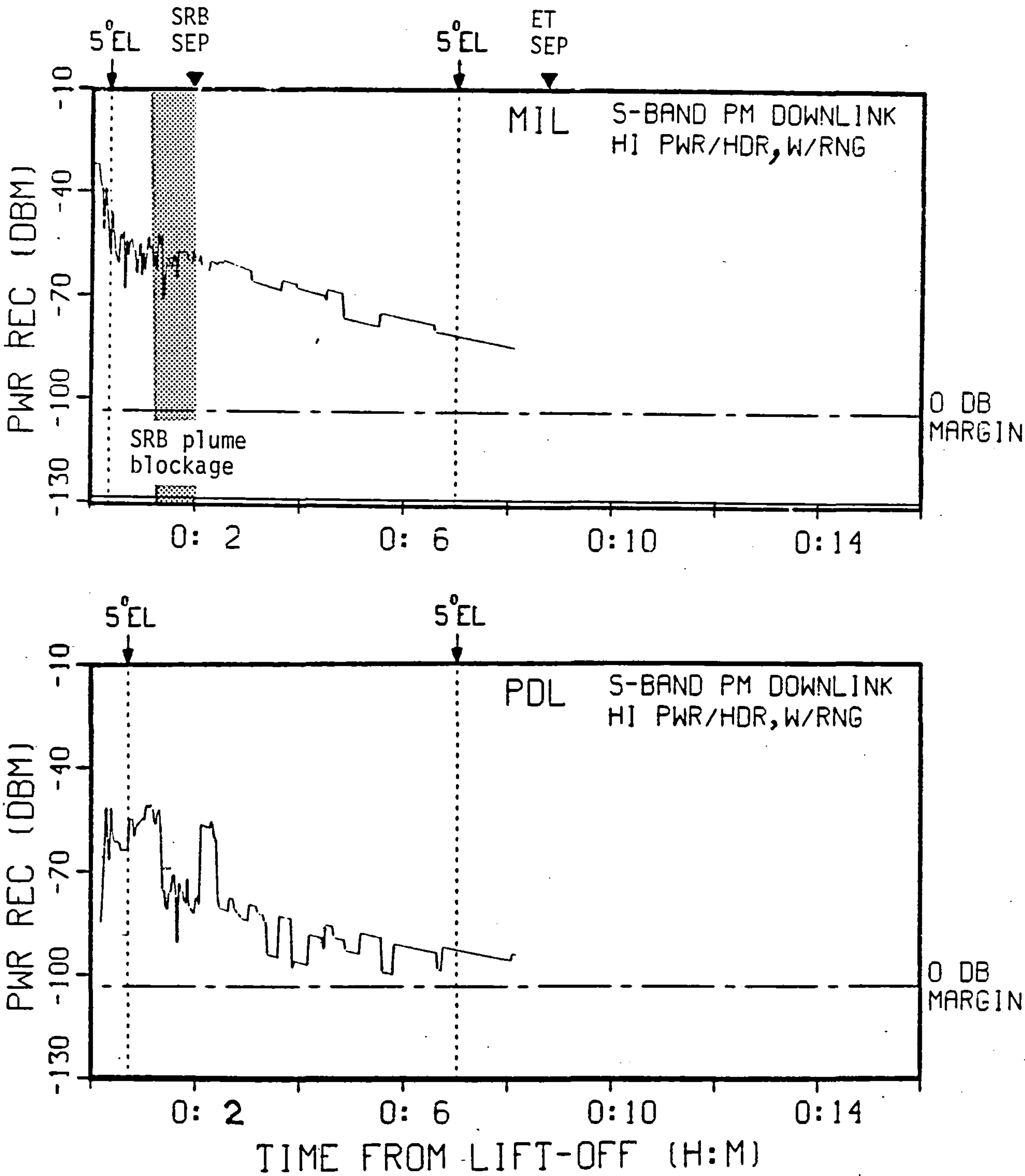
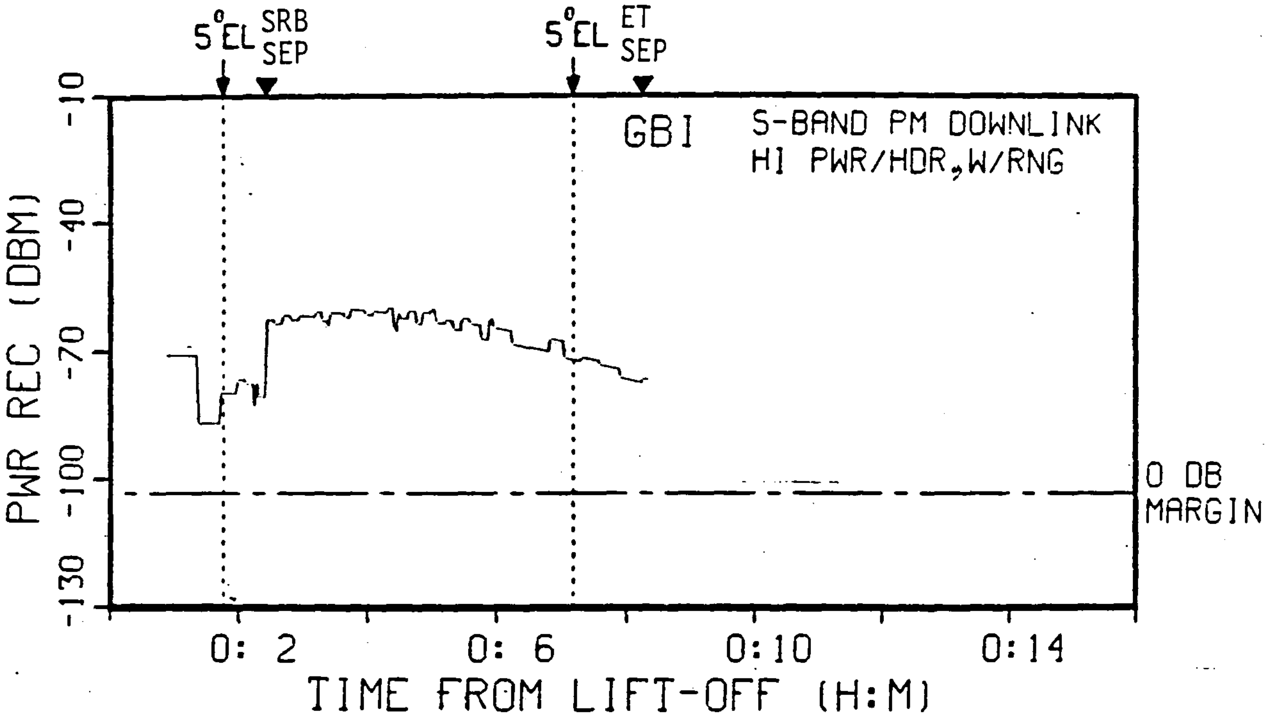


Figure 3-1.- Shuttle S-band PM downlink predicted RF signal power at MIL, PDL, GBI and BDA during STS-2 ascent (reference trajectory: Cycle 2).



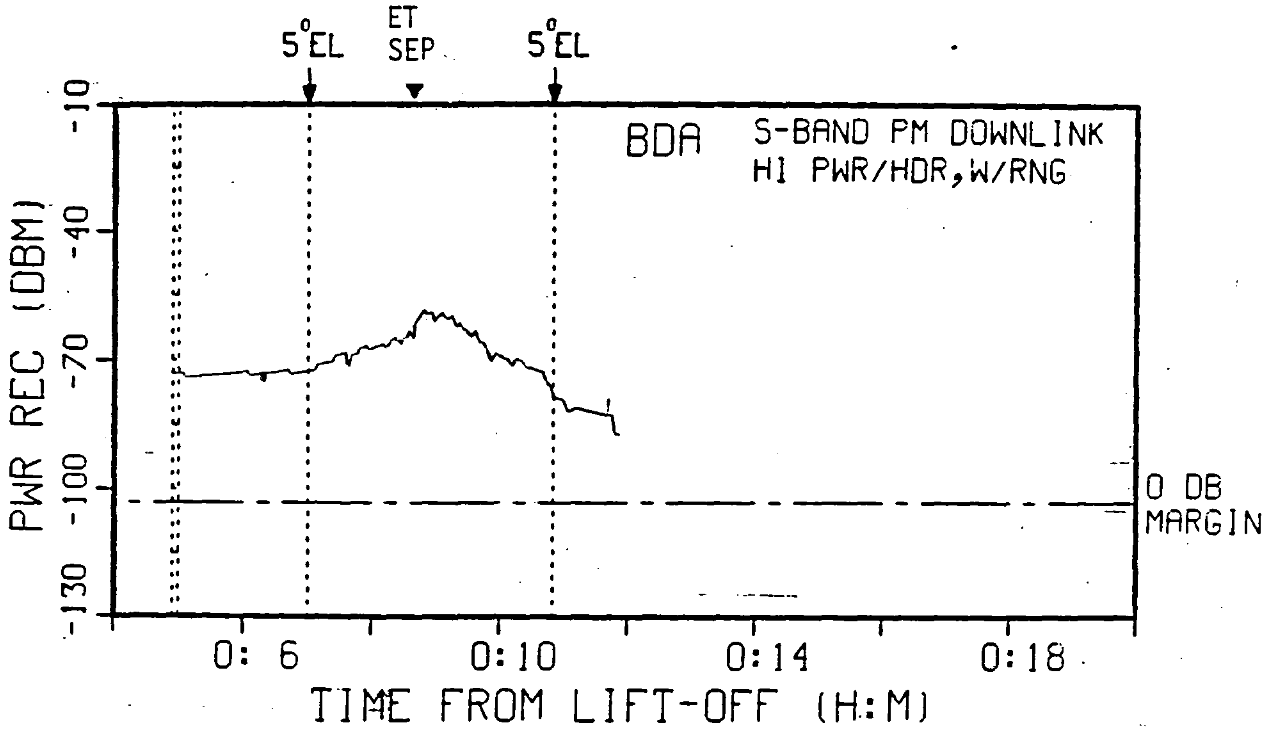
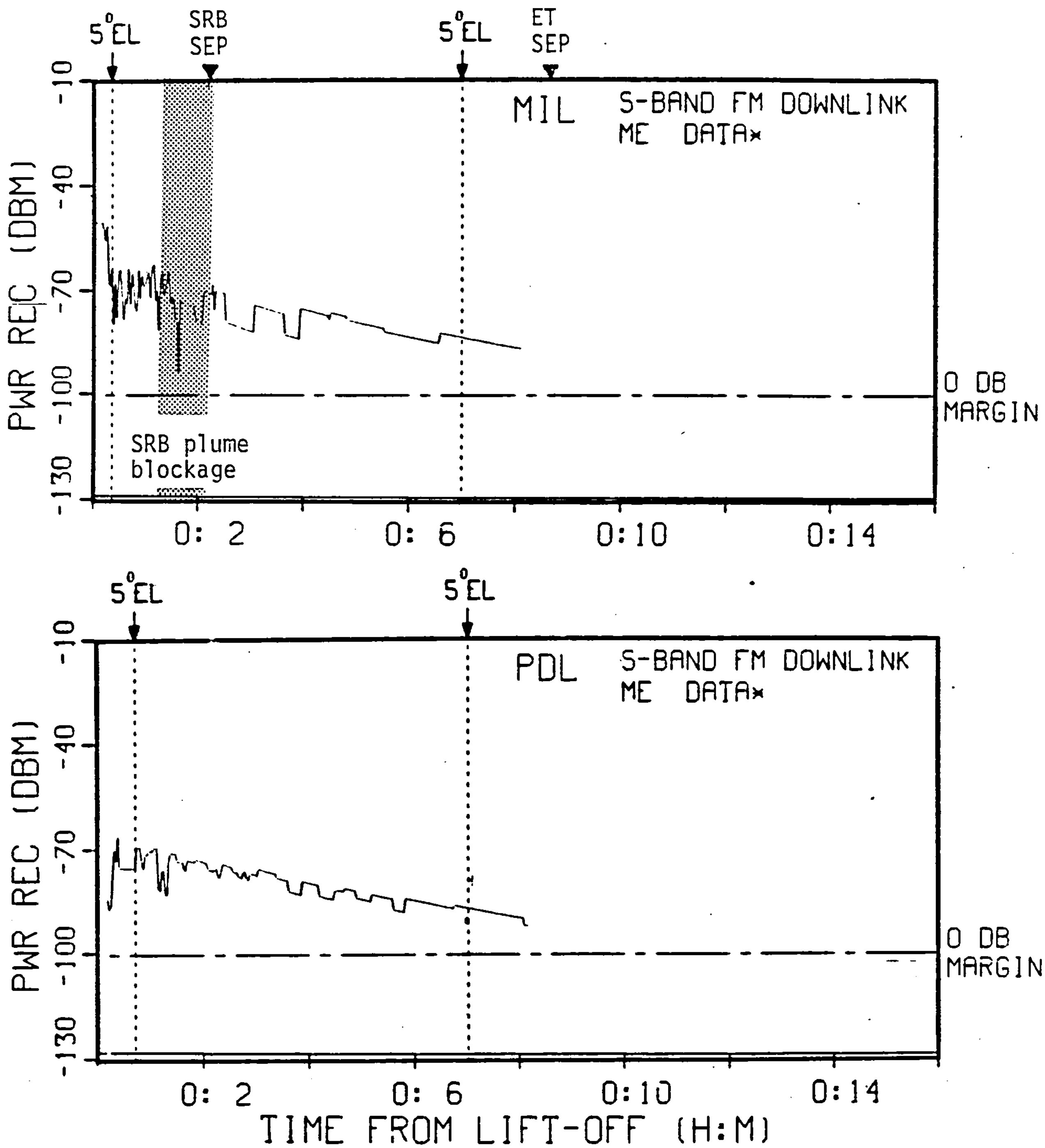
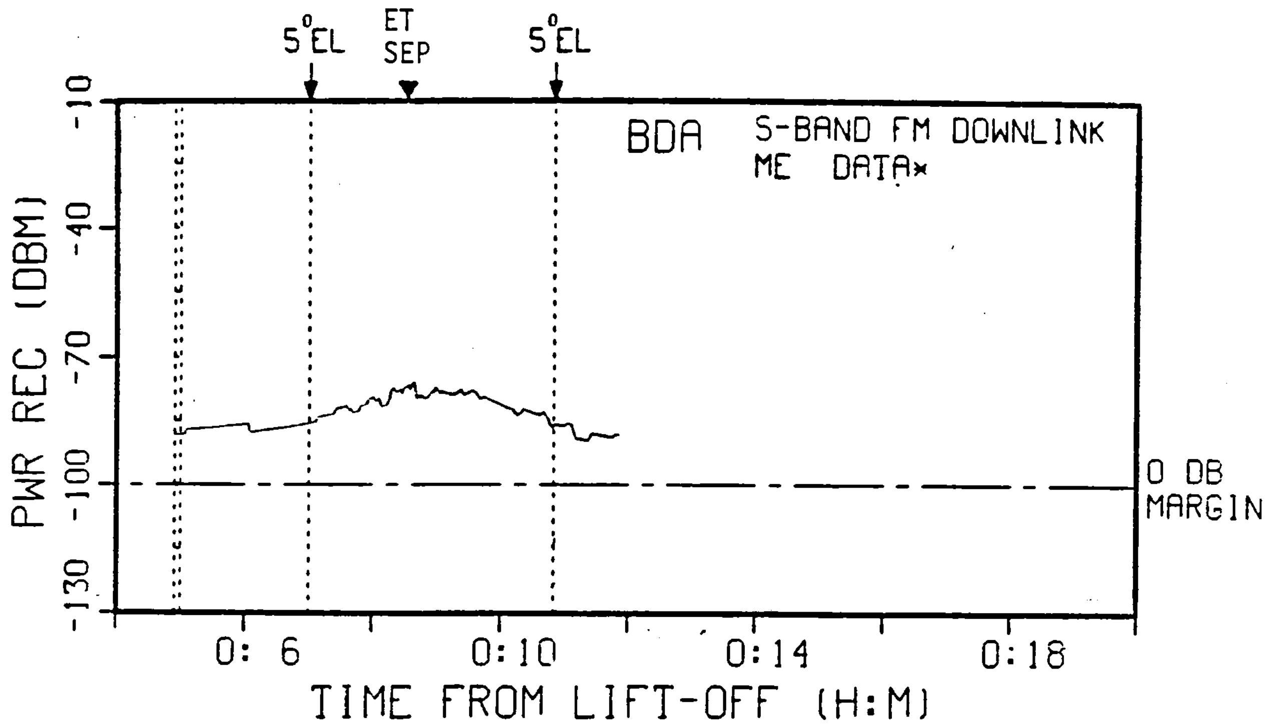


Figure 3-1.- Concluded.



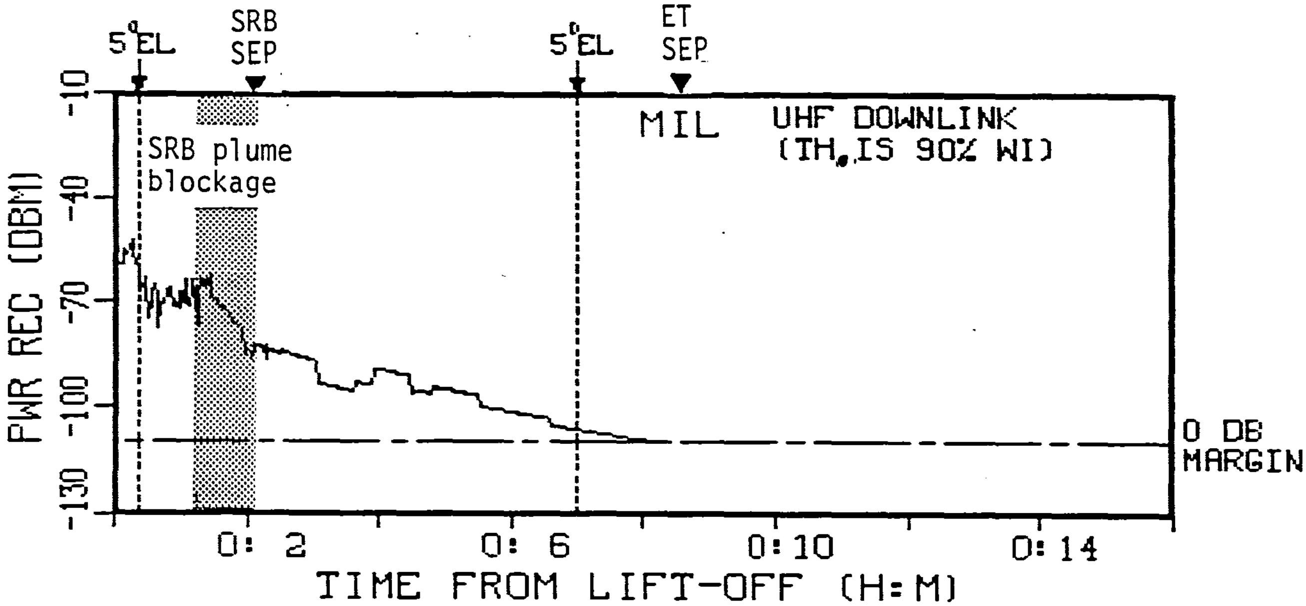
*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 3-2.- Shuttle S-band FM downlink predicted RF signal power at MIL, PDL, and BDA during STS-2 ascent (reference trajectory: Cycle 2).



*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 3-2.- Concluded.



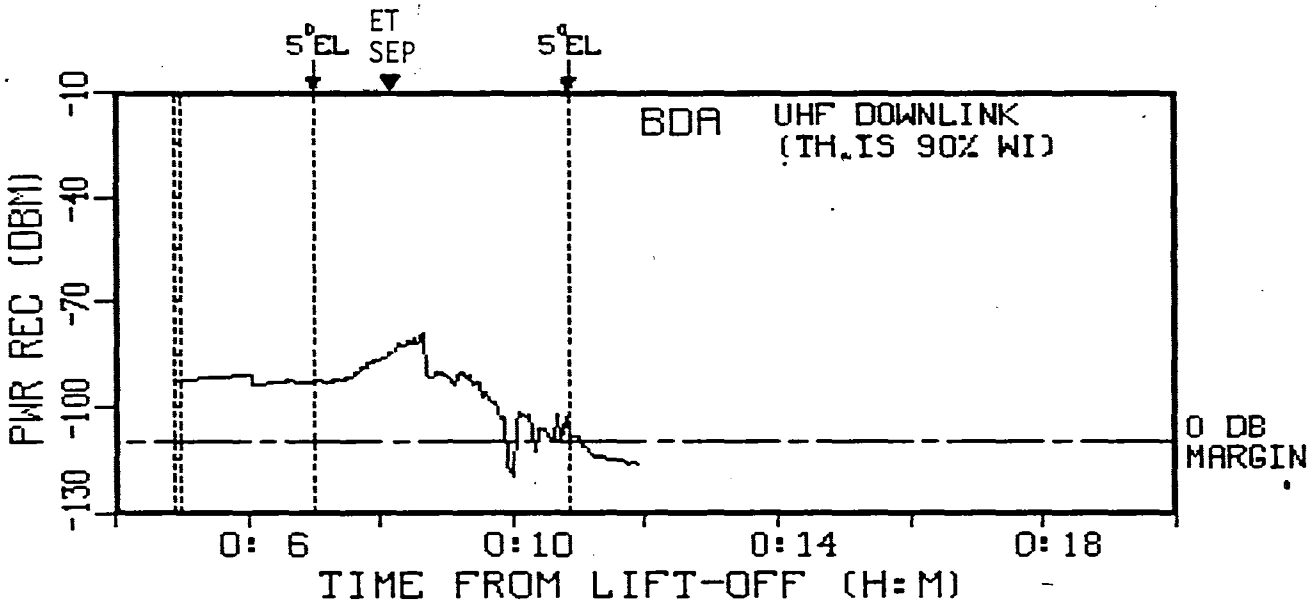


Figure 3-3.- Shuttle UHF voice downlink predicted RF signal power at MIL and BDA during STS-2 ascent (reference trajectory: Cycle 2).

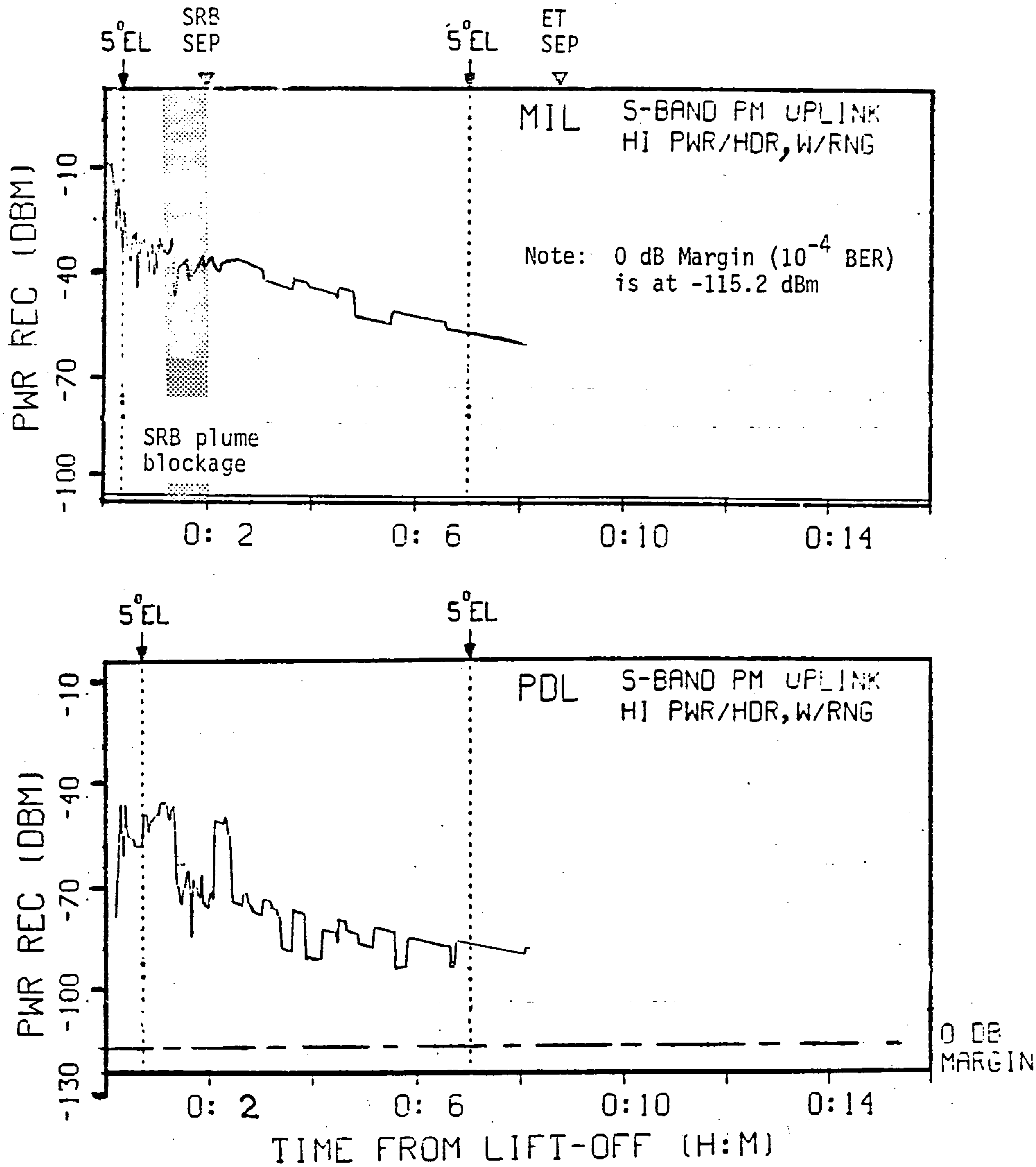


Figure 3-4.- Shuttle S-band PM uplink predicted RF signal power for MIL, PDL, and BDA during STS-2 ascent (reference trajectory: Cycle 2).

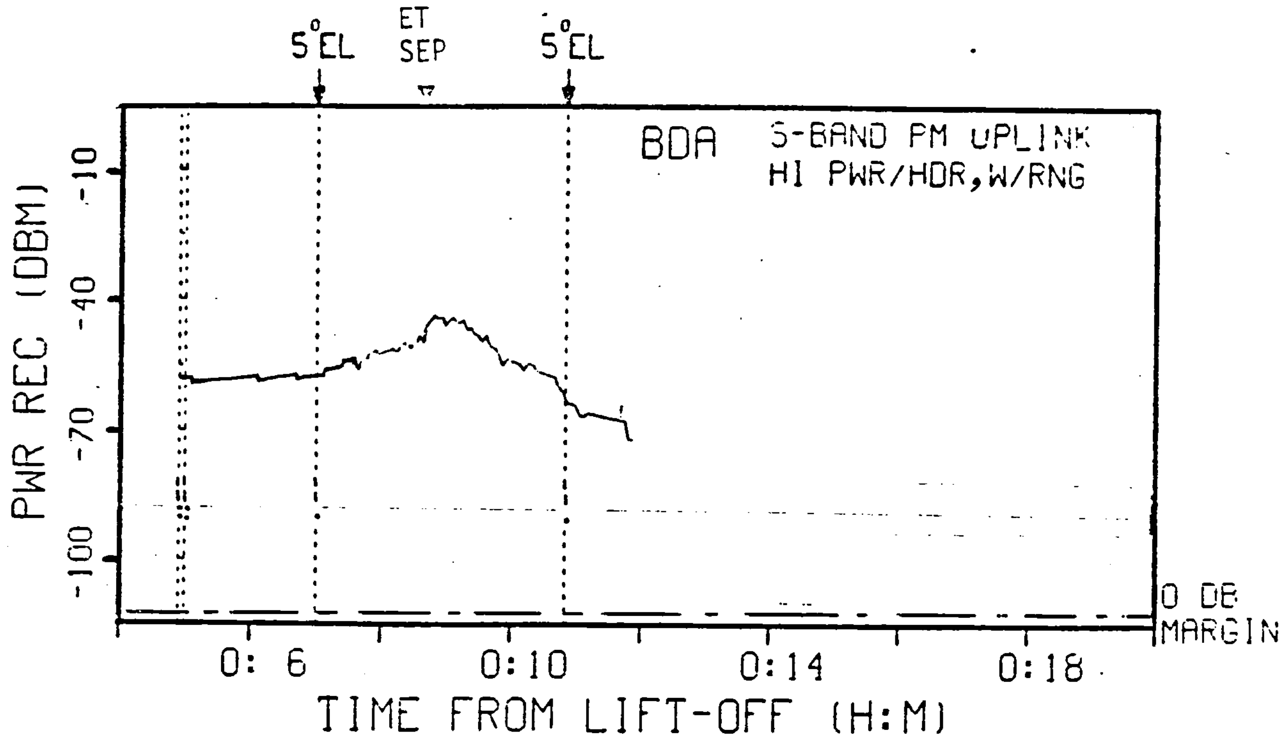


Figure 3-4.- Concluded.

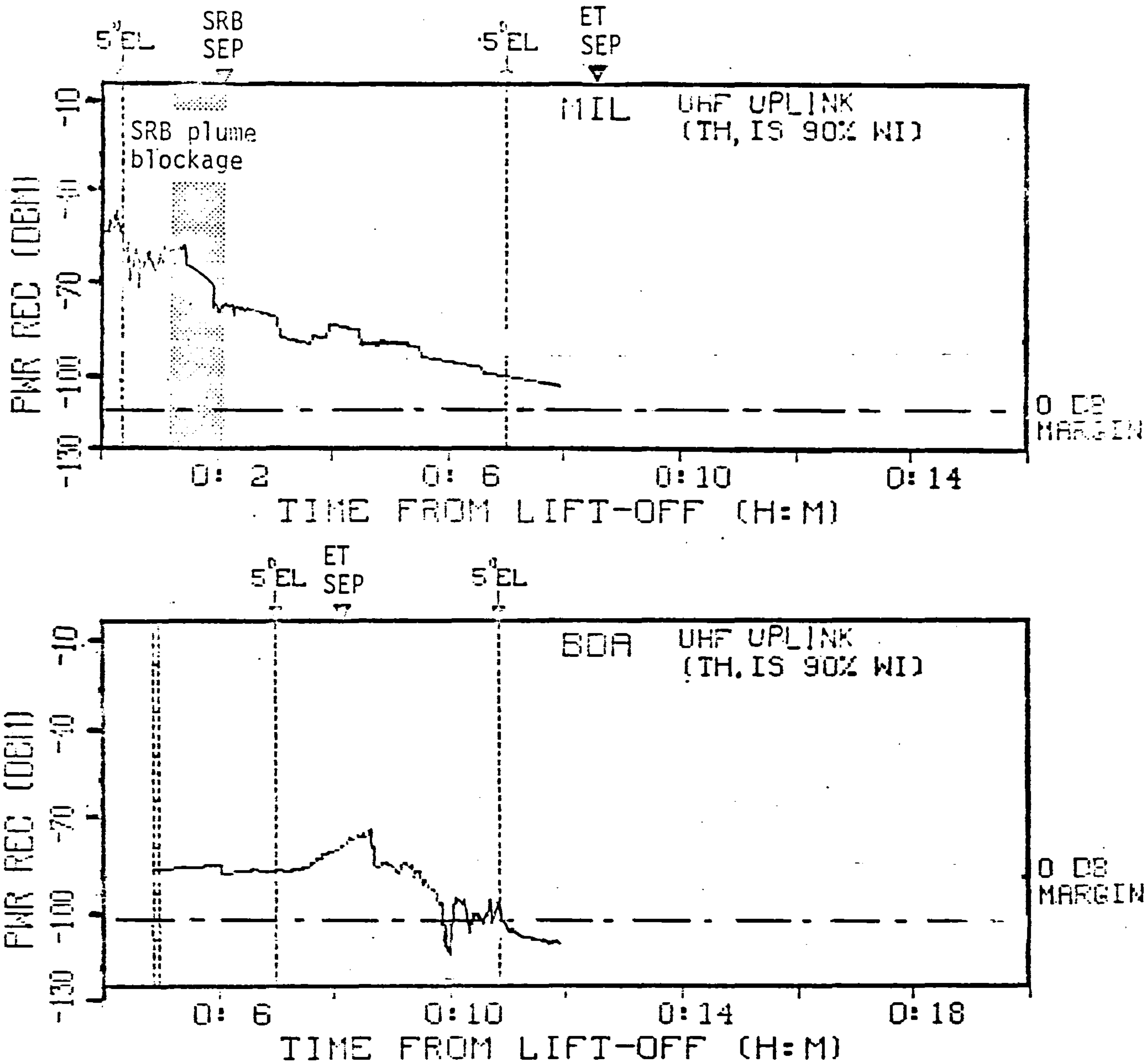


Figure 3-5.- Shuttle UHF voice uplink predicted RF signal power for MIL and BDA during STS-2 ascent (reference trajectory: Cycle 2).

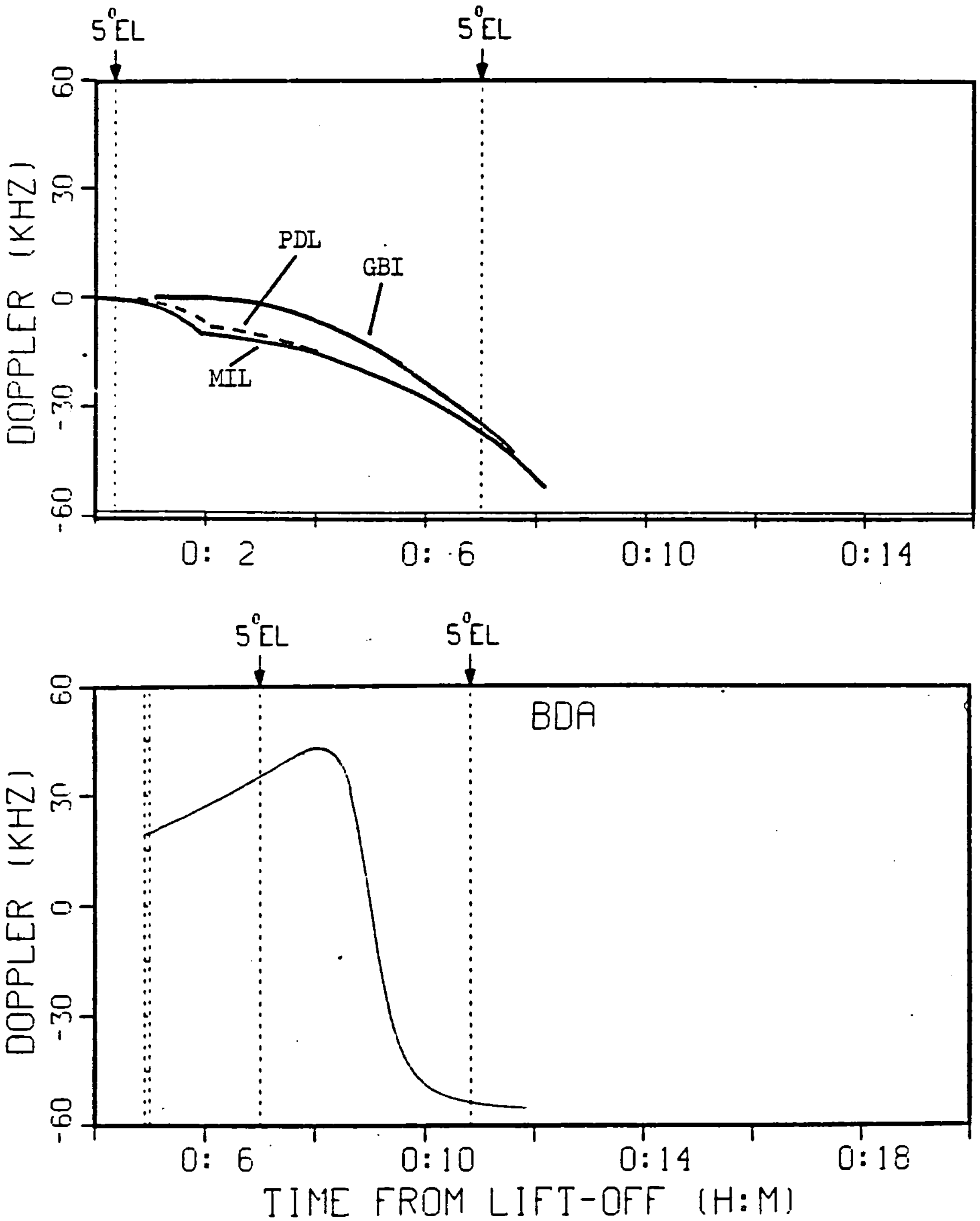


Figure 3-6.- Ascent Doppler, one-way (2287.5 MHz); MIL, PDL, GBI, BDA (STS-2 Cycle 2 trajectory).

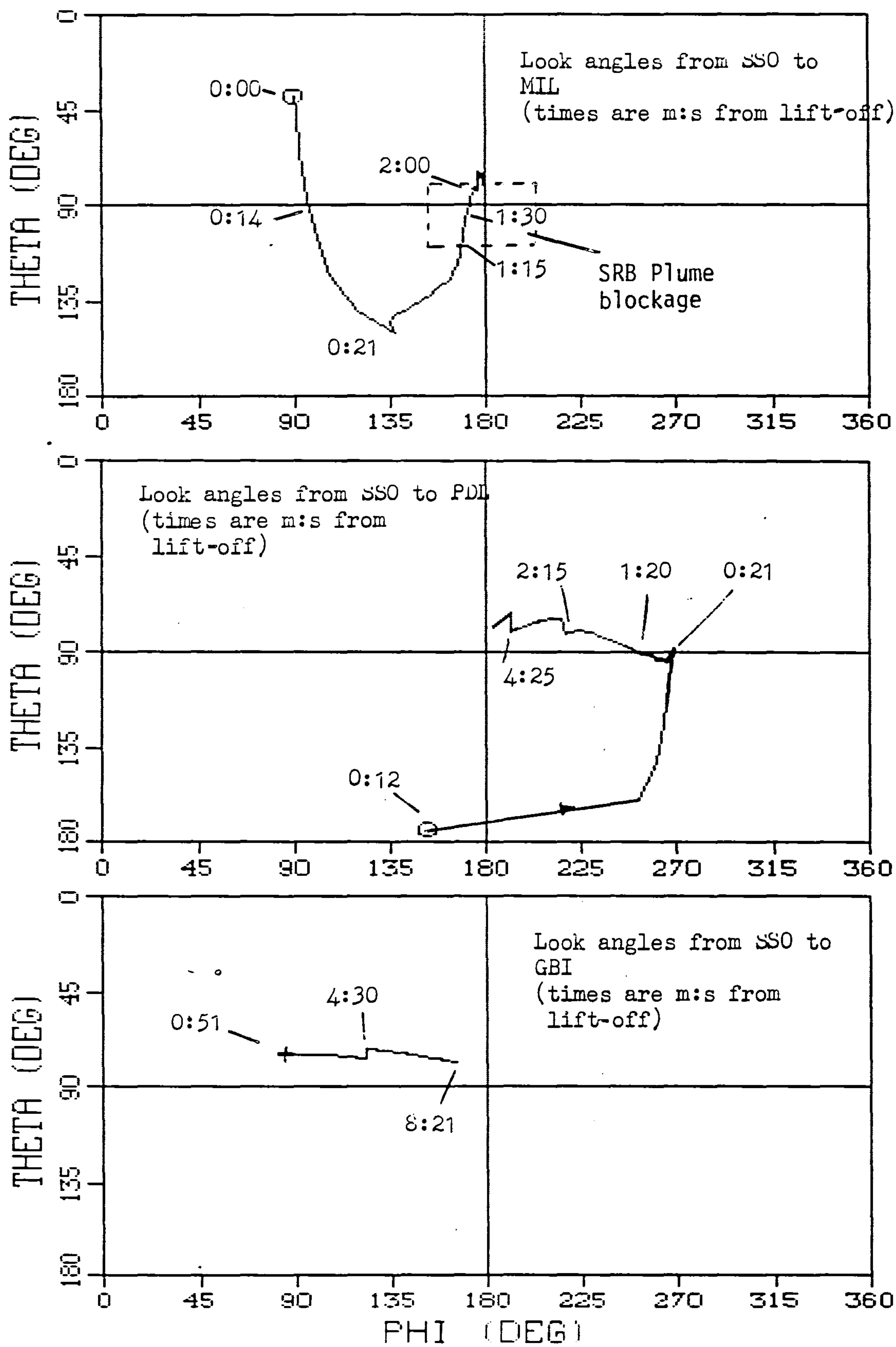


Figure 3-7.- Shuttle look angles to MIL, PDL, GBI and BDA during STS-2 nominal ascent (reference trajectory: Cycle 2).

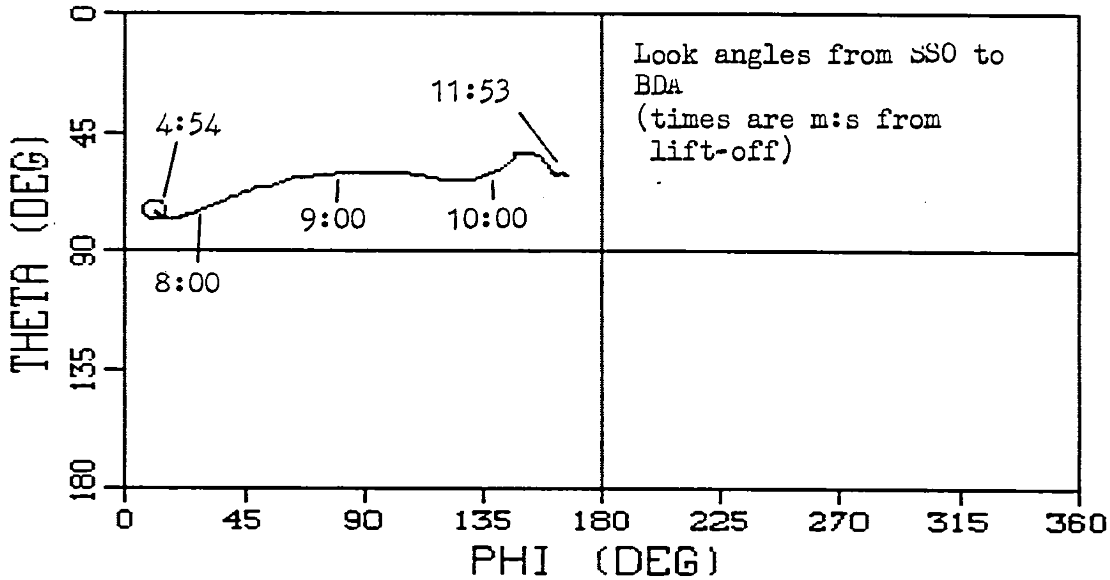
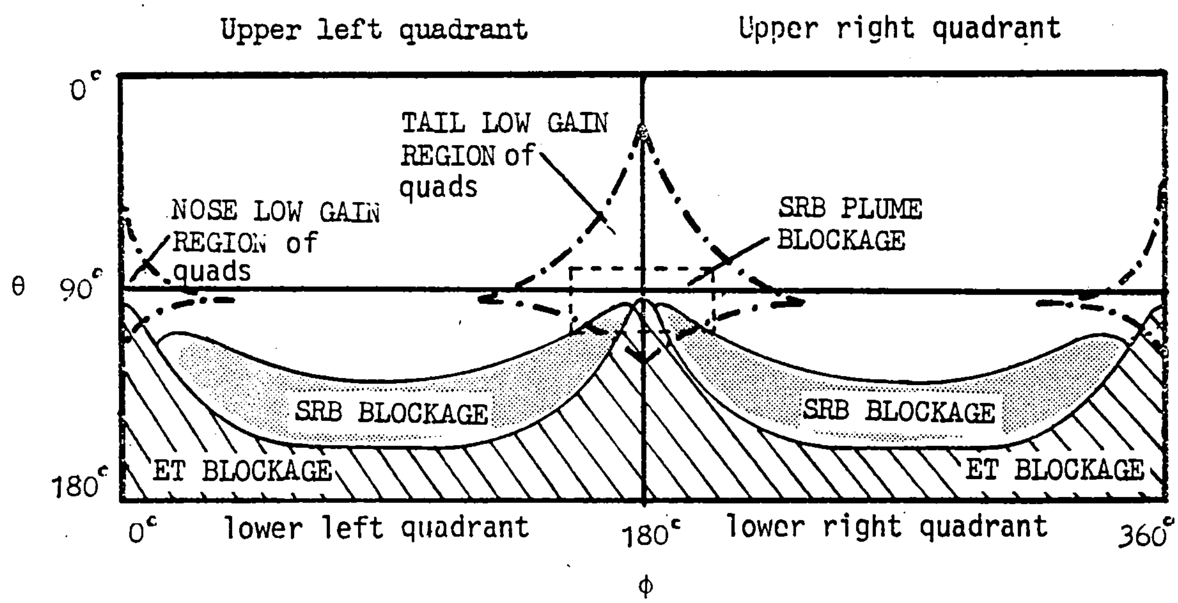


Figure 3-7.- Concluded.



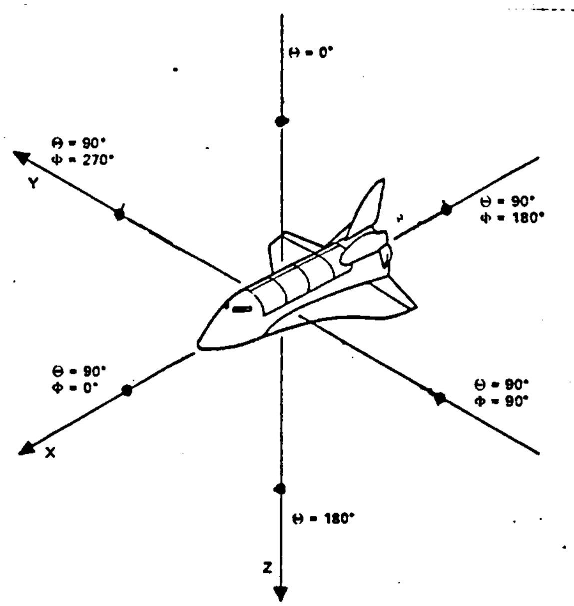
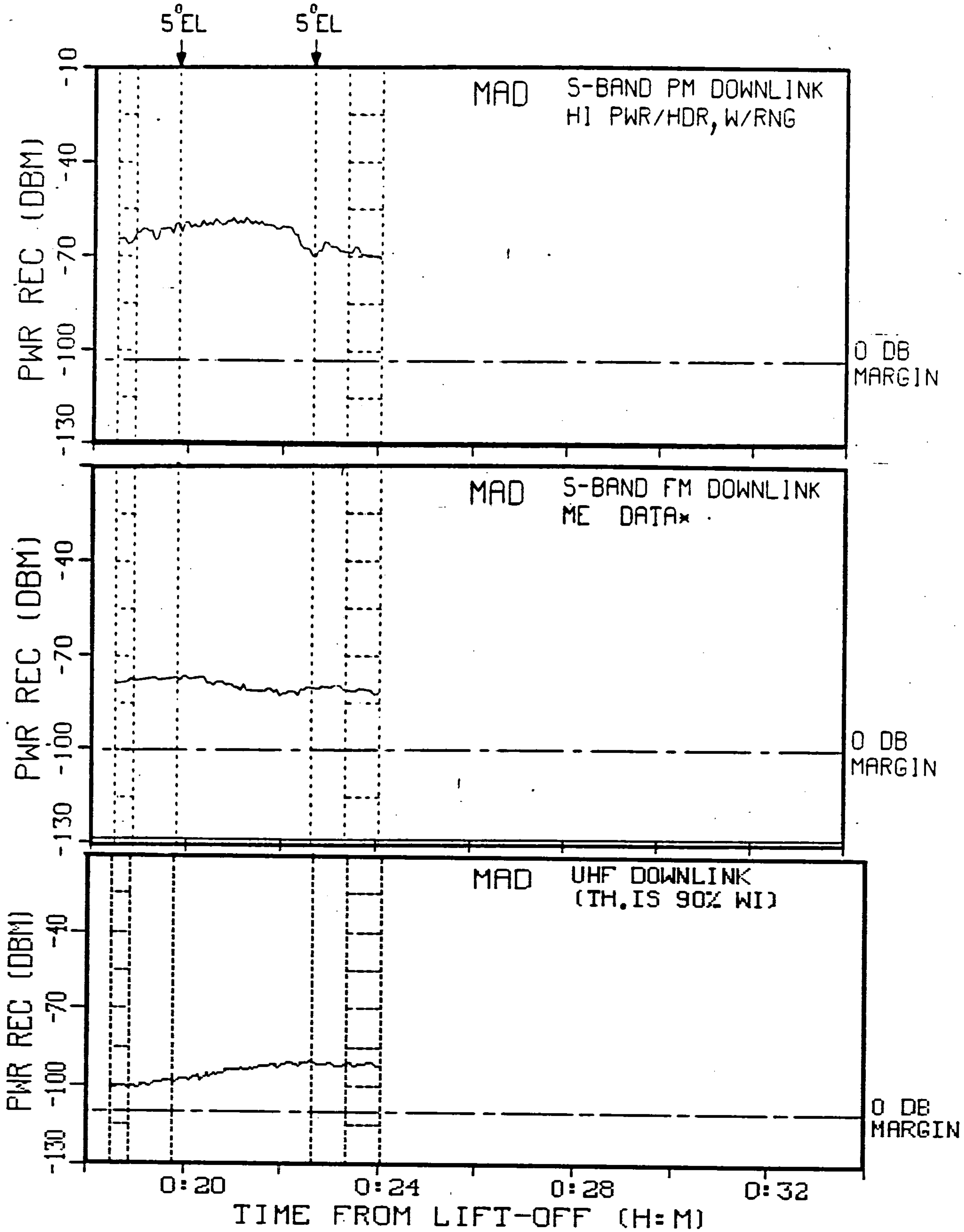
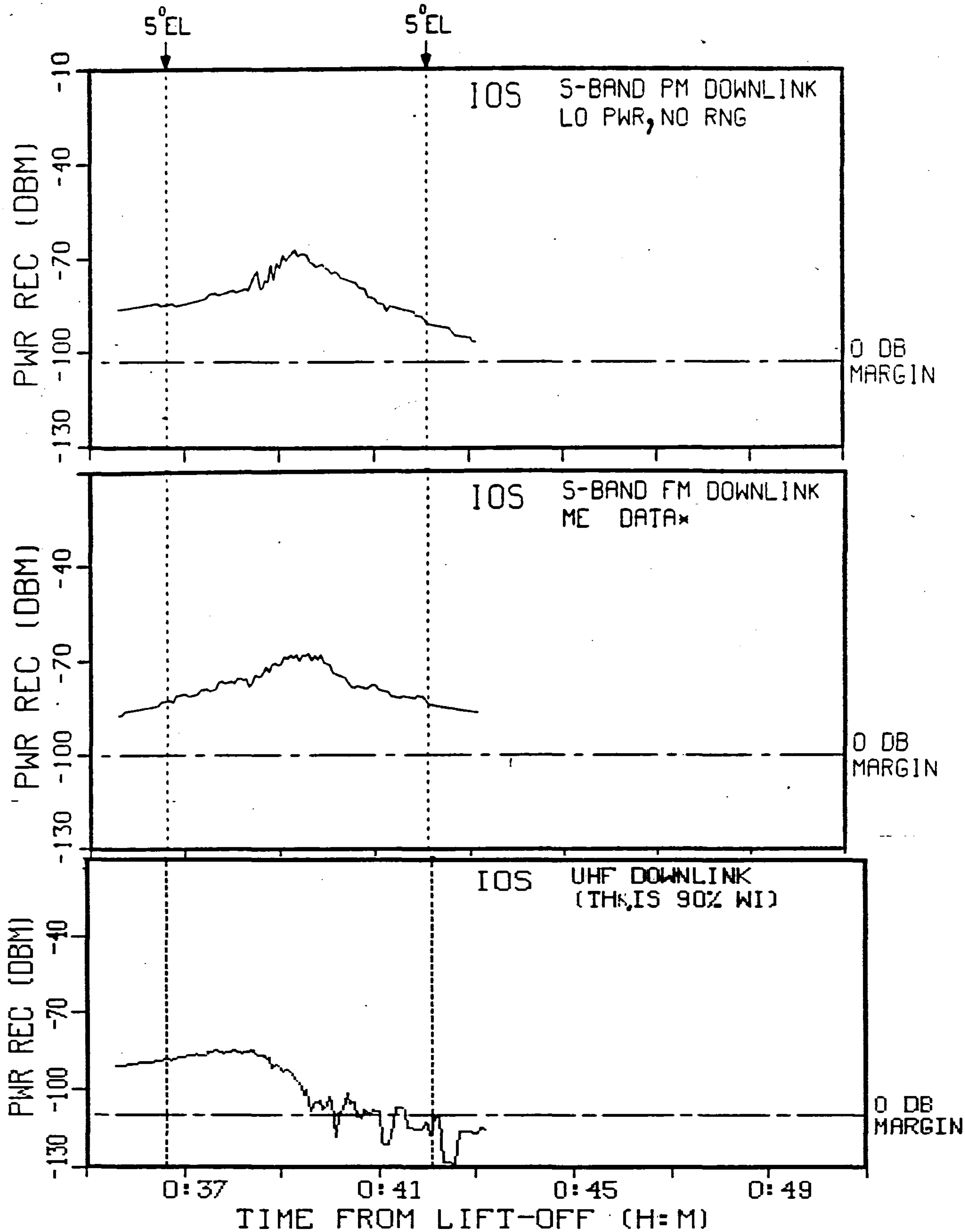


Figure 3-8.- Shuttle ascent-phase line-of-sight blockage by SRB exhaust plume (MIL only) and vehicle structure; and low-gain regions of quad antennas.



*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 3-9.- Shuttle downlink predicted RF signal power at MAD during STS-2 ascent (reference trajectory: Cycle 2).



*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 3-10.- Shuttle downlink predicted RF signal power at IOS during STS-2 ascent (reference trajectory: Cycle 2).

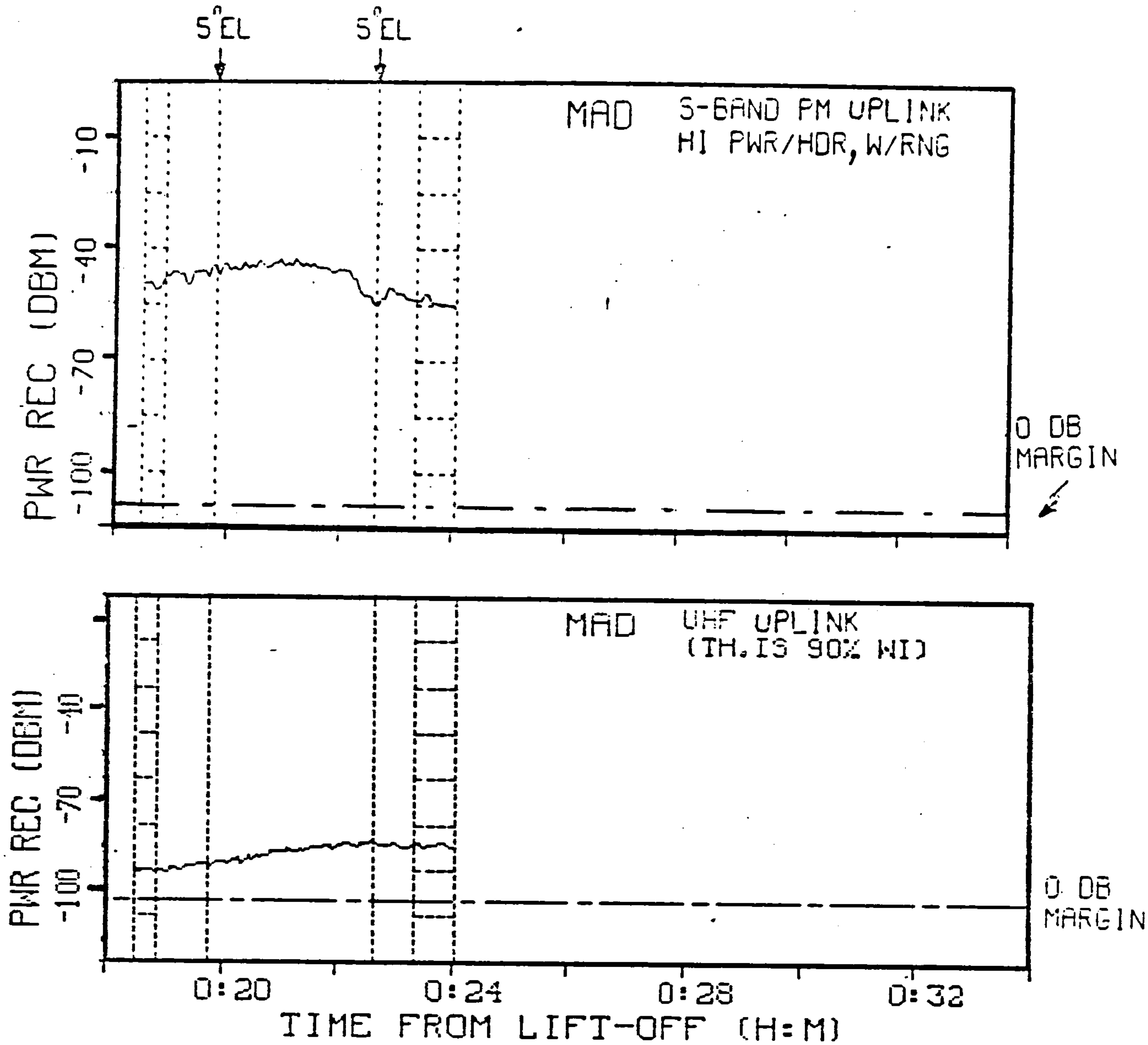


Figure 3-11.- Shuttle uplink predicted RF signal power for MAD during STS-2 ascent (reference trajectory: Cycle 2).

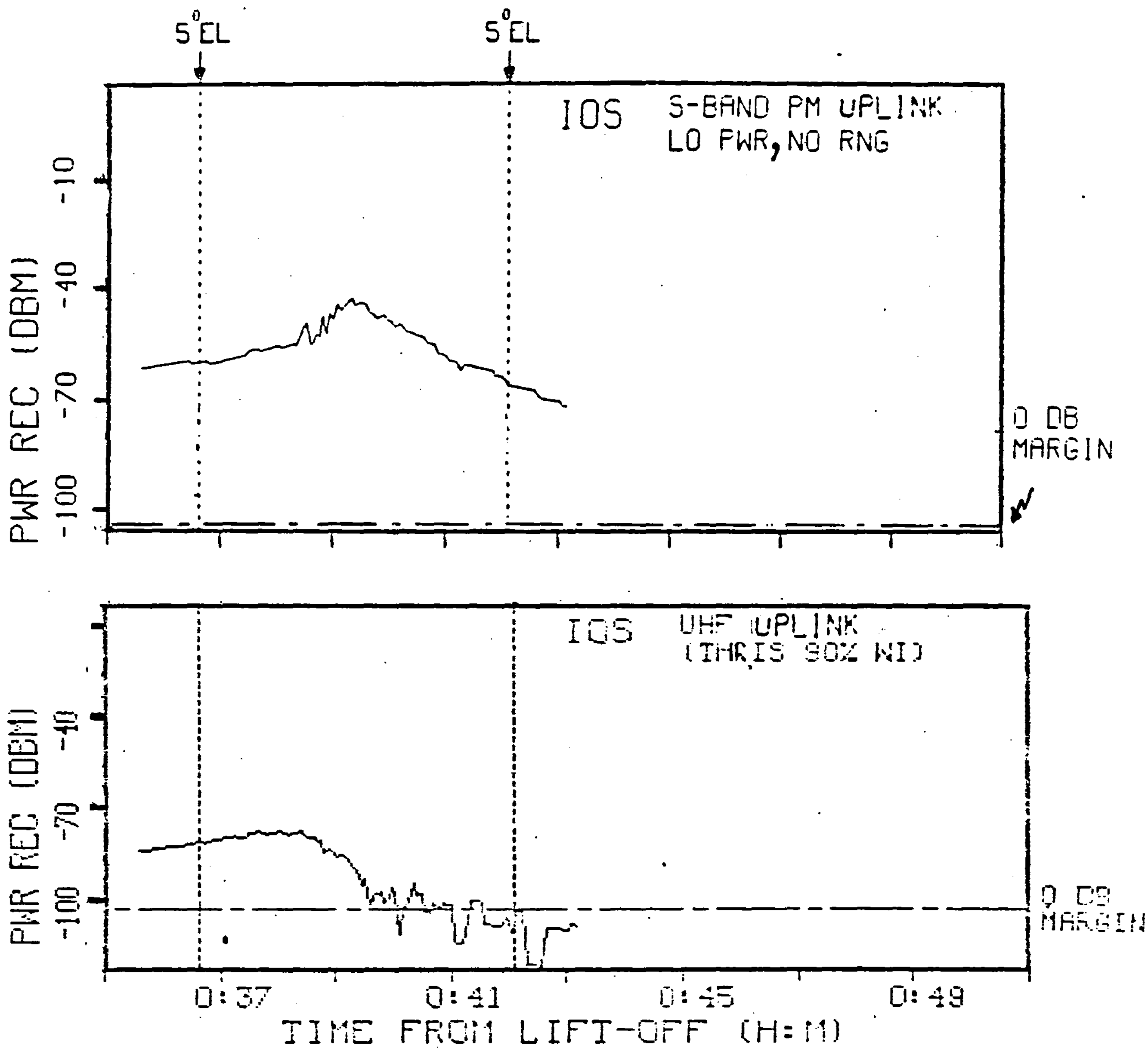


Figure 3-12.- Shuttle uplink predicted RF signal power for IOS during STS-2 ascent (reference trajectory: Cycle 2).

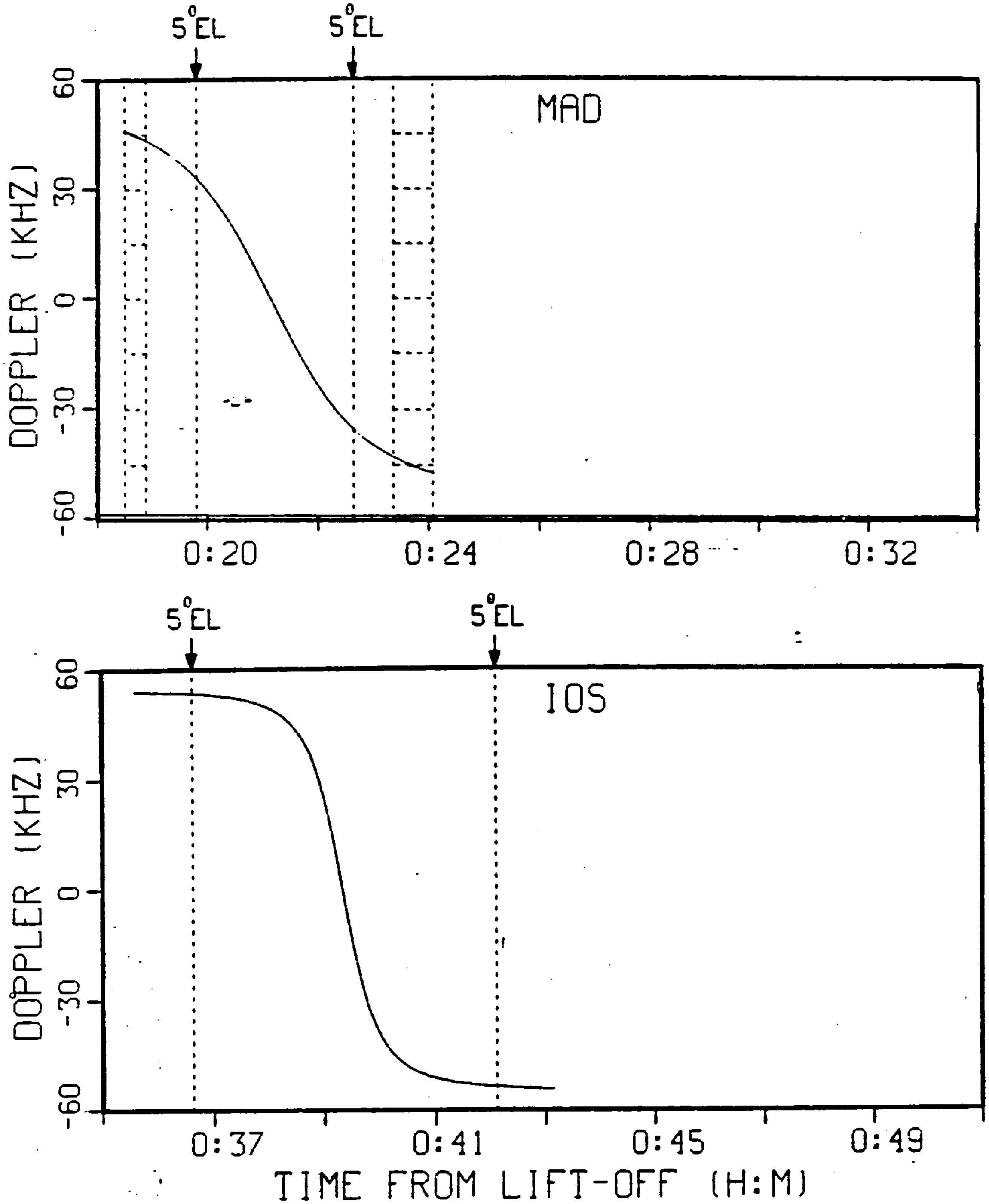


Figure 3-13.- Ascent Doppler, one-way (2287.5 MHz); MAD and IOS (STS-2 Cycle 2 trajectory).

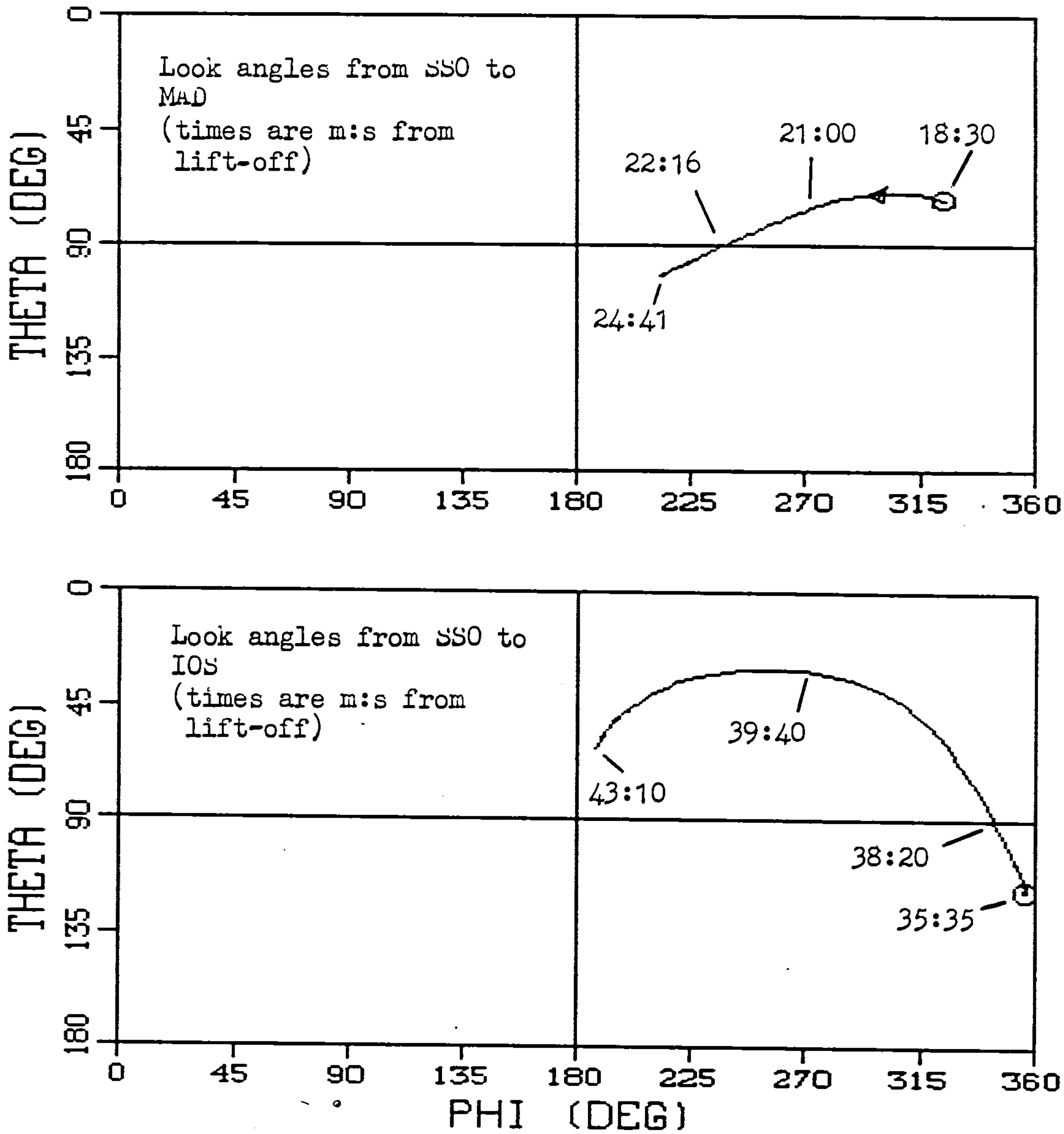


Figure 3-14.- Shuttle look angles to MAD and IOS during STS-2 nominal ascent (reference trajectory: Cycle 2).

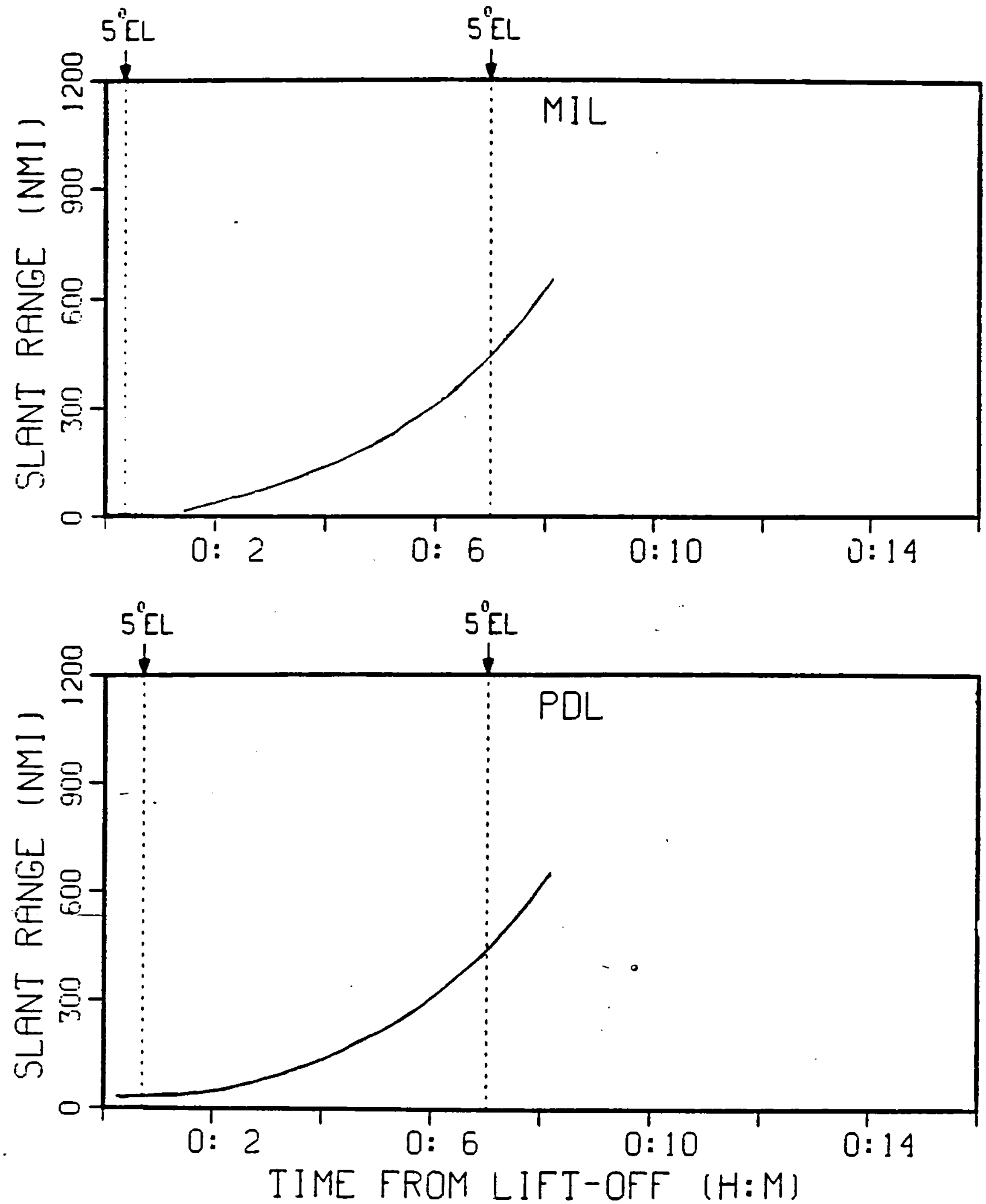


Figure 3-15.- Predicted slant range from the Shuttle to ground stations for STS-2 ascent (reference trajectory: Cycle 2).

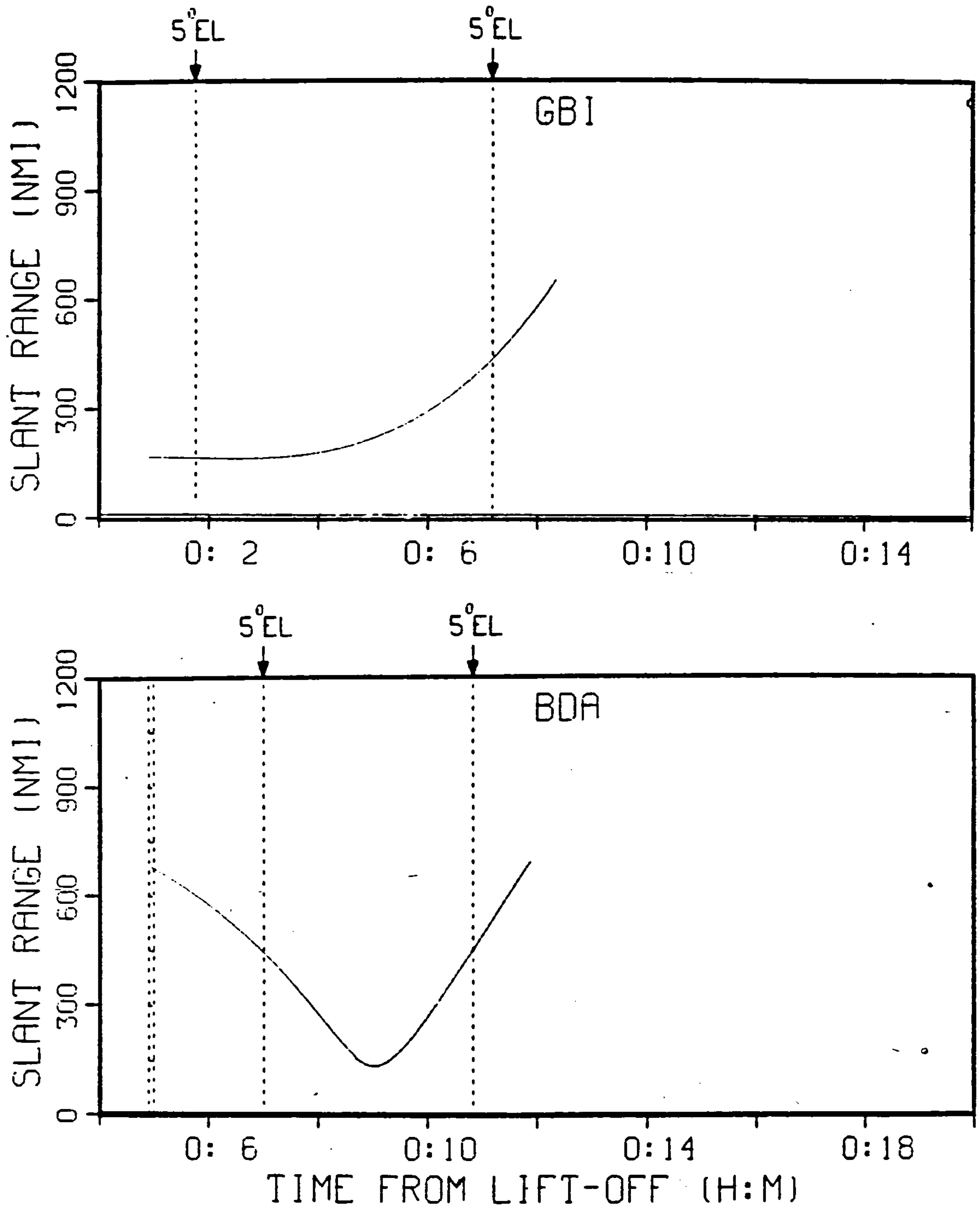


Figure 3-15.- Continued.

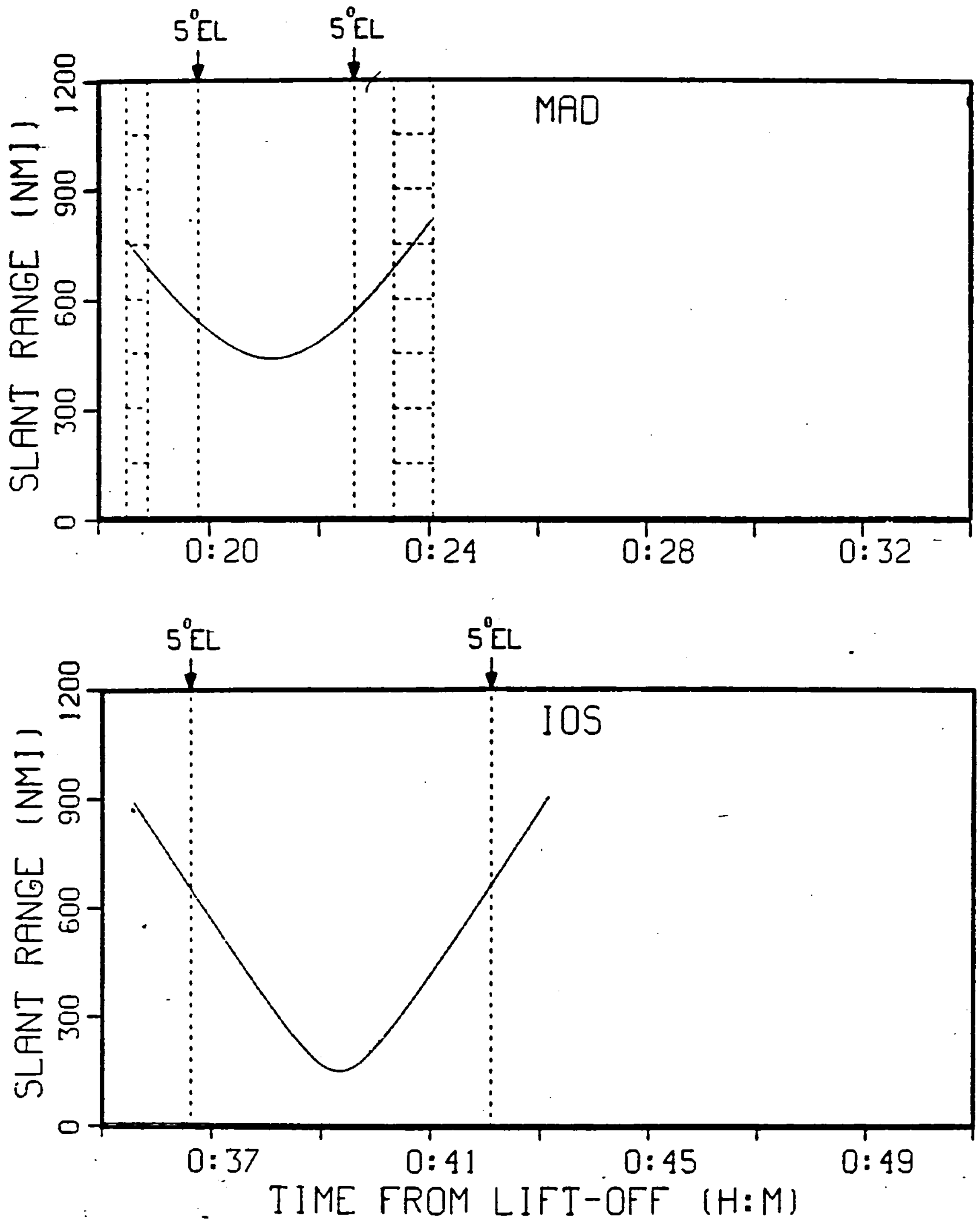


Figure 3-15.- Concluded.

TABLE 3-I.- SSO-GROUND STATION COMMUNICATION LINKS CAPABILITY SUMMARY (ASCENT PHASE, STS-2)

Ground station	S-band PM		S-band FM		UHF voice	
	Downlink	Uplink	OI	DFI	Downlink	Uplink
MIL	yes	yes	R	yes	yes	yes
PDL	yes	yes	R	yes	no	no
GBI	yes	no	no	no	no	no
BDA	yes	yes	R	yes	yes	yes
MAD	yes	yes	R	yes	yes	yes
IOS	yes	yes	R	yes	yes	yes

Note: All PM and UHF data are available real time.
R - Recorded.

TABLE 3-II.- SHUTTLE STS-2 ASCENT PHASE RF LINK CHARACTERISTICS, DIRECT LINKS WITH GSTDN

(a) S-band PM, quad antennas, direct links with MIL, BDA, and PDL

Downlink

SSO transmit power (2 W for IOS)	100 W
SSO transmit circuit loss (4.8 dB for IOS)	6.4 dB
Polarization loss	0.1 dB
MIL and BDA receive antenna gain (PDL = 36.8 dB, MAD = 53.2 dB, IOS = 48.2 dB)	43.5 dB
Data rate	192 kbps
Ranging	ON

Uplink

MIL transmit power (PDL = 200 W, BDA, MAD = 2 kW, IOS = 1 kW)	
MIL and BDA transmit antenna gain (including circuit loss)	10 kW
(PDL = 36.8 dB, MAD = 50.5 dB, IOS = 42.7 dB)	43 dB
Polarization loss	0.1 dB
SSO receive circuit loss (4.6 dB for preamp off)	4.3 dB
Data rate	72 kbps
Ranging (IOS OFF)	ON
Convolutional Encoding (MAD, IOS OFF) (72 kbps into 216 kbps)	ON

(b) S-band FM, hemi antennas (downlink only)

SSO transmit power	10 W
SSO transmit circuit loss (DFI channel = 11.2 dB)	9.4 dB
Polarization loss	0.1 dB
MIL and BDA receive antenna gain (PDL - 36.8 dB, MAD = 53.2 dB, IOS = 48.2 dB)	43.5 dB

(c) UHF (voice only)

Downlink

SSO transmit power	10 W
SSO transmit circuit loss	2.9 dB
SSO voice clipping	9 dB
SSO transmit modulation index	0.9
Polarization loss	3 dB
MIL, MAD, and IOS effective antenna gain (no UHF at PDL) (BDA = 17.5 dB)	18.5 dB

Uplink

MIL, BDA, MAD, and IOS transmit power	100 W
MIL, MAD, and IOS effective antenna gain (BDA = 15.4 dB)	16.4 dB
MIL, BDA, MAD, and IOS voice clipping	4.5 dB
MIL, BDA, MAD, and IOS transmit modulation index	0.9
Polarization loss	3 dB
SSO receive circuit loss	2.9 dB

4. ASCENT RF COMMUNICATIONS PERFORMANCE PREDICTIONS FOR STS-1 ABORT CASES (AOA, RTLS)

Three types of abort have been defined (ref. 4) for ascent: abort-to-orbit (ATO) abort-once-around (AOA), and return to launch site (RTLS). As far as communication links are concerned, ATO behavior is very similiar to a nominal ascent. However, AOA and RTLS are considerably different and data for these is given in this section. A comparison of STS-1 ascent nominal and abort-trajectory ground tracks is given by figure 4-1.

4.1 AOA Ascent RF Coverage

The AOA trajectory is very similar to nominal ascent for the first 5 minutes. For the AOA trajectory, the ascent phase ends at operation 3, the transition into entry mode, just prior to the MAD pass. However, for completeness, both MAD and IOS station pass data will be included. The requirement for continuous S-band voice and telemetry communications through MECO plus 1 minute is satisfied for STS-2 AOA using MIL (plus PDL, and GBI as necessary, to cover the plume period) and then handing over to BDA. MIL, PDL, GBI, and BDA signal-strength profiles for AOA ascent for S-band PM, S-band FM, and UHF voice, are given by figures 4-2 to 4-4, and Doppler plots by figure 4-5. Figures 4-2 to 4-4 are downlink plots; they predict the downlinks will be strong all the way through the end of the BDA pass, except UHF voice may be somewhat less than the 90-percent WI level for the last couple of minutes. (The uplinks are similar but stronger and hence are not shown.) Look-angles are plotted in figure 4-6 for the same periods and stations. Figures 4-7 to 4-10 give the analogous data for the next two ground station passes, MAD and IOS. Slant range is plotted for all six stations (MIL, PDL, GBI, BDA, MAD, and IOS) in figure 4-11.

4.2 RTLS RF Coverage

RTLS aborts, as was evident from figure 4-1, are quite different from AOA. The decision to RTLS-abort is made prior to about 270 seconds GET; an abort after this becomes an AOA or ATO abort. The time the decision is made obviously affects the shape of the return trajectory and range, elevation, etc. to the ground stations. However, the RTLS trajectory is the same as that of a normal ascent from lift-off through SRB-SEP.

The subsequent flight profile is divided into three general parts, as illustrated by figure 4-12: headsdown-powered flight, pitcharound, and glide-to-landing. These are considered separately in the following paragraphs. Only the early RTLS (one ME out at lift-off) case is considered here. There are several possible RTLS abort trajectories, and the real abort may differ considerably.

4.2.1 Headsdown-Powered Coverage

During this period, the SSO flies headsdown in its normal attitude during ascent. The elevation angle at MIL is always greater than 5° above the horizon and the S-band PM link to MIL will be more than 20 dB strong for HDR telemetry and ranging, as illustrated in the appropriate time period of figure 4-13.

4.2.2 Pitcharound and ET Separation Coverage

During pitcharound, when the SSO changes from headsdown to an upright position, figures 4-13 to 4-15 show severe signal-strength fluctuations, S-band and UHF, particularly when the ET temporarily blocks the link of sight. Antenna pattern data indicates fluctuations of 20 to 30 dB during ET shadowing. The ground test-range measured antenna data is considered to be less reliable in these regions, and if the actual S-band PM quad antenna gain in the ET blockage region is worse than the measured data, possible loss of signal may occur and reacquisition may be necessary. Figure 4-16 gives Doppler and figure 4-17 give the look angles to MIL, PDL, GBI, and BDA for the entire RTLS flight, for the early case. Slant range is given in figure 4-18.

4.2.3 Glide Return to Launch Site (GRTLS) Coverage

After ET separation, the line of sight becomes clear and the S-band PM, S-band FM, and UHF links are predicted to remain strong until landing.

4.3 TACAN RF Coverage

TACAN coverage is required for RTLS as early as possible, for navigation purposes. During the pitchover and ET-separation phase, the TACAN link will

probably not be very reliable, due to shadowing and rapid attitude changes. For the glide-to-landing phase, TACAN 2-LRU lock should be obtained as early as 220-kft* altitude, the start of the glide phase. Figure 4-19 gives TACAN station locations and figure 4-20 shows the predicted TACAN range and bearing 2-LRU lock-on history for early RTLS. The KSC mobile station (SCP) and Patrick AFB (COF) will provide STS-2 TACAN coverage for RTLS.

4.4 MSBLS RF Coverage

MSBLS coverage is required approximately the last 18 kft of the descent. Plots of predicted RF link margin for the DME uplink, elevation uplink and azimuth uplink channels under different rainfall conditions are shown in figure 4-21.

The MSBLS system utilizes two ground station groups, the azimuth/DME group and the elevation group. The onboard MSBLS set interrogates the ground stations to obtain information in a manner similar to TACAN. The azimuth and elevation information is transmitted in coded form from their respective ground stations and then decoded onboard. Since MSBLS operates in Ku-band, it is very susceptible to rain, as indicated by the margin curves in figure 4-21.

MSBLS is required to perform to about 10 nmi; figure 4-21 indicates this requirement can be met for rainfall up to 10 mm/hr.

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*RTLS descent has a much higher 2-LRU-acquisition altitude than the nominal end-of-mission descent (see volume II). The slant range at 220-kft altitude for this RTLS descent is comparable to the slant range at about 160-kft altitude for nominal end-of-mission descent.

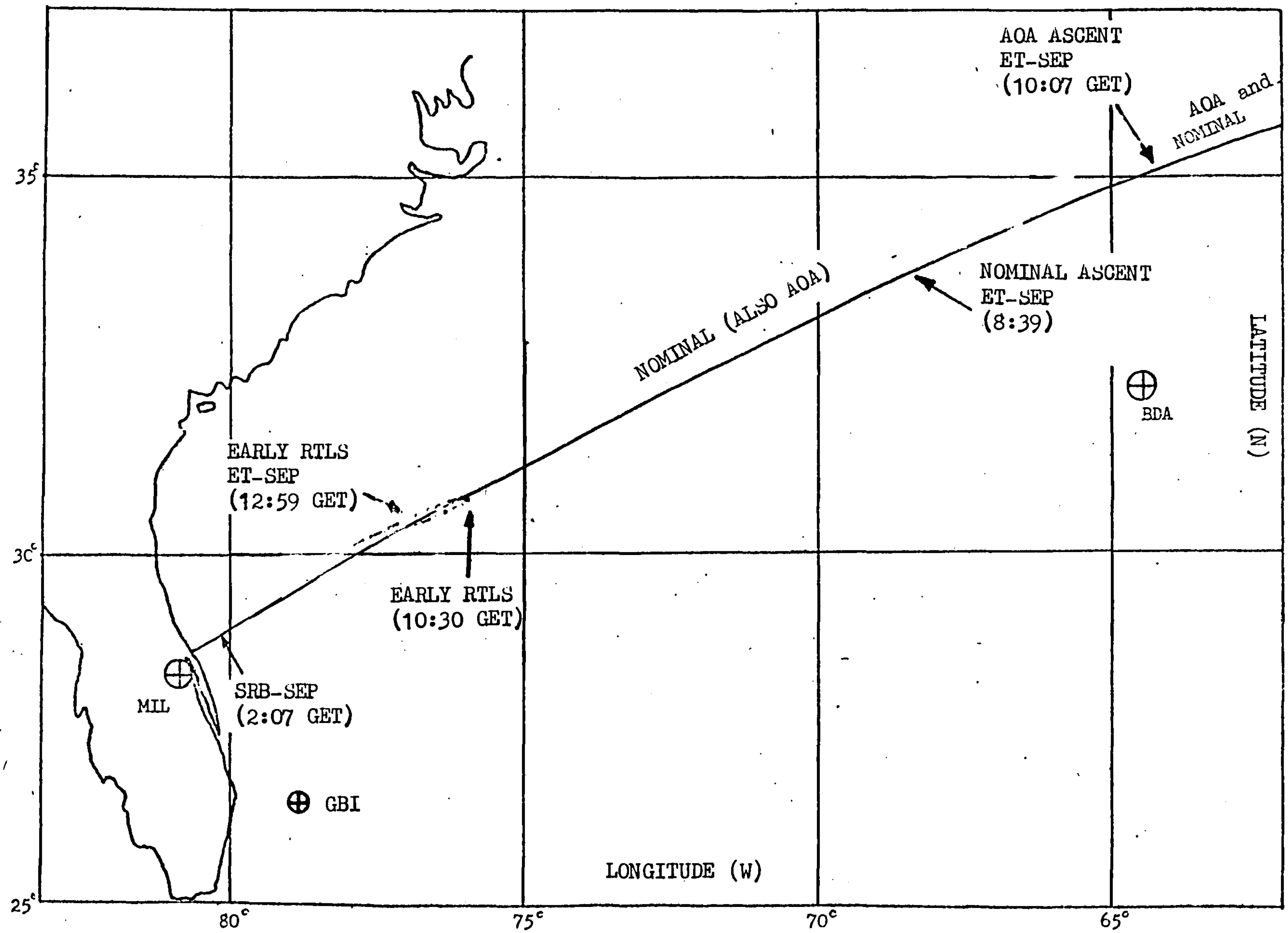


Figure 4-1.- Comparison of nominal and abort (AOA, RTLS) trajectories for STS-2 ascent (reference trajectory: Cycle 2).

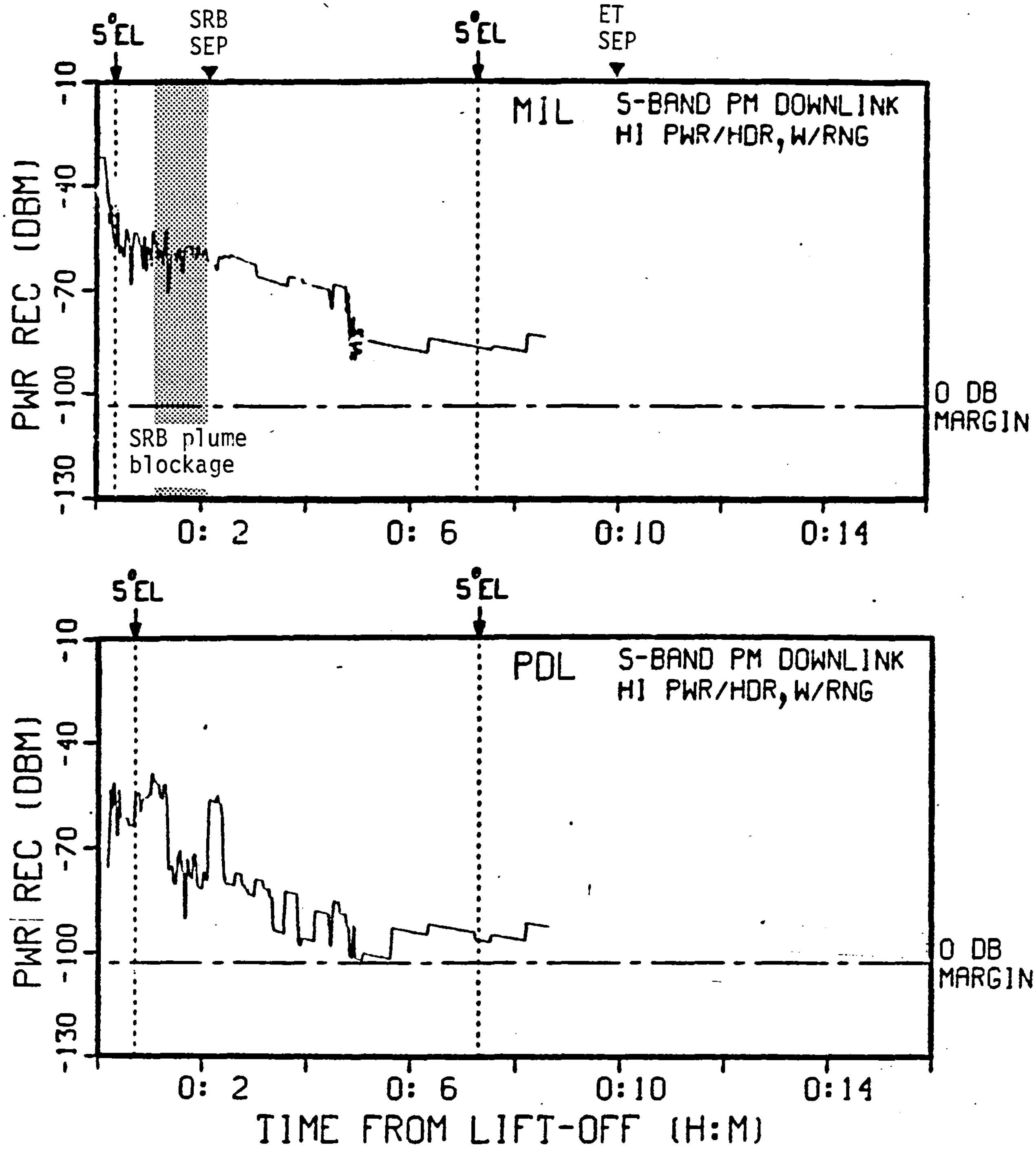


Figure 4-2.- Shuttle S-band PM downlink predicted signal power at MIL, PDL,GBI and BDA during STS-2 AOA ascent (reference trajectory: Cycle 2).

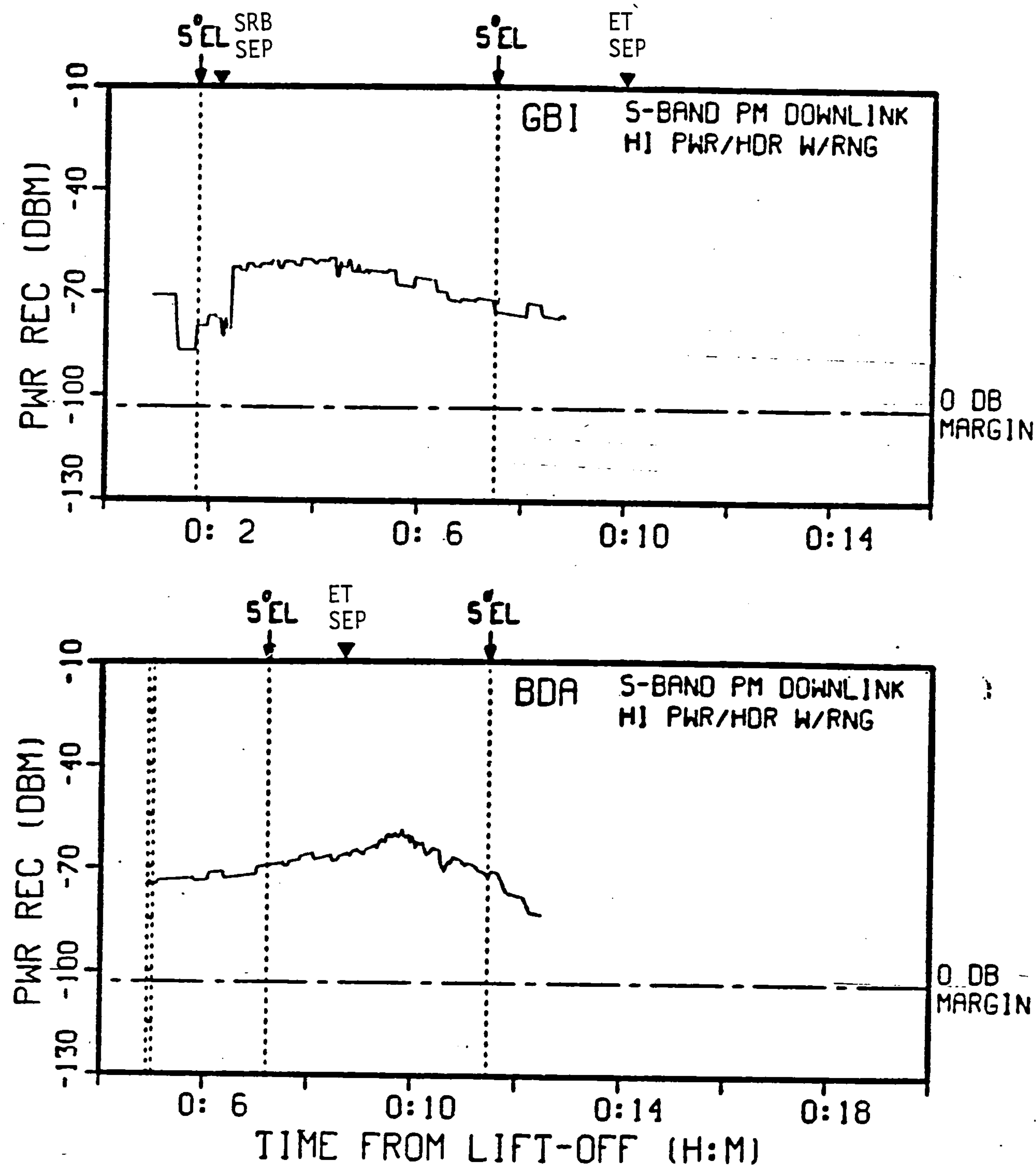
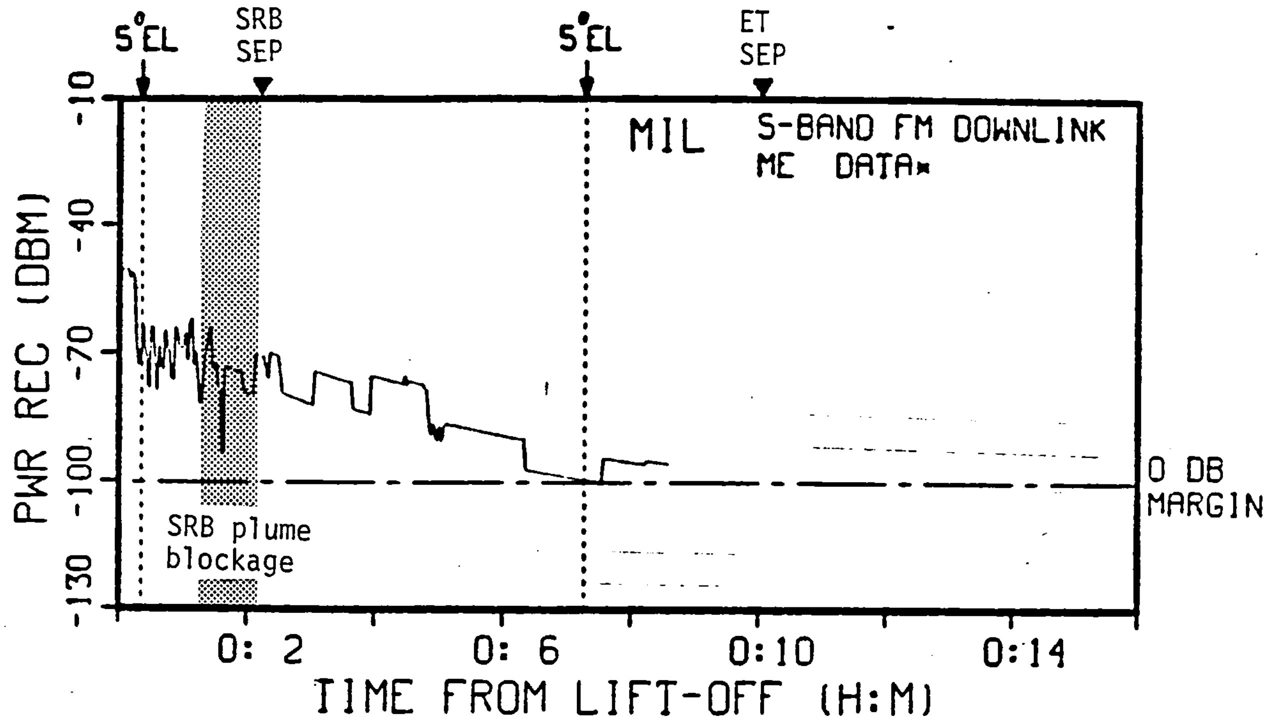
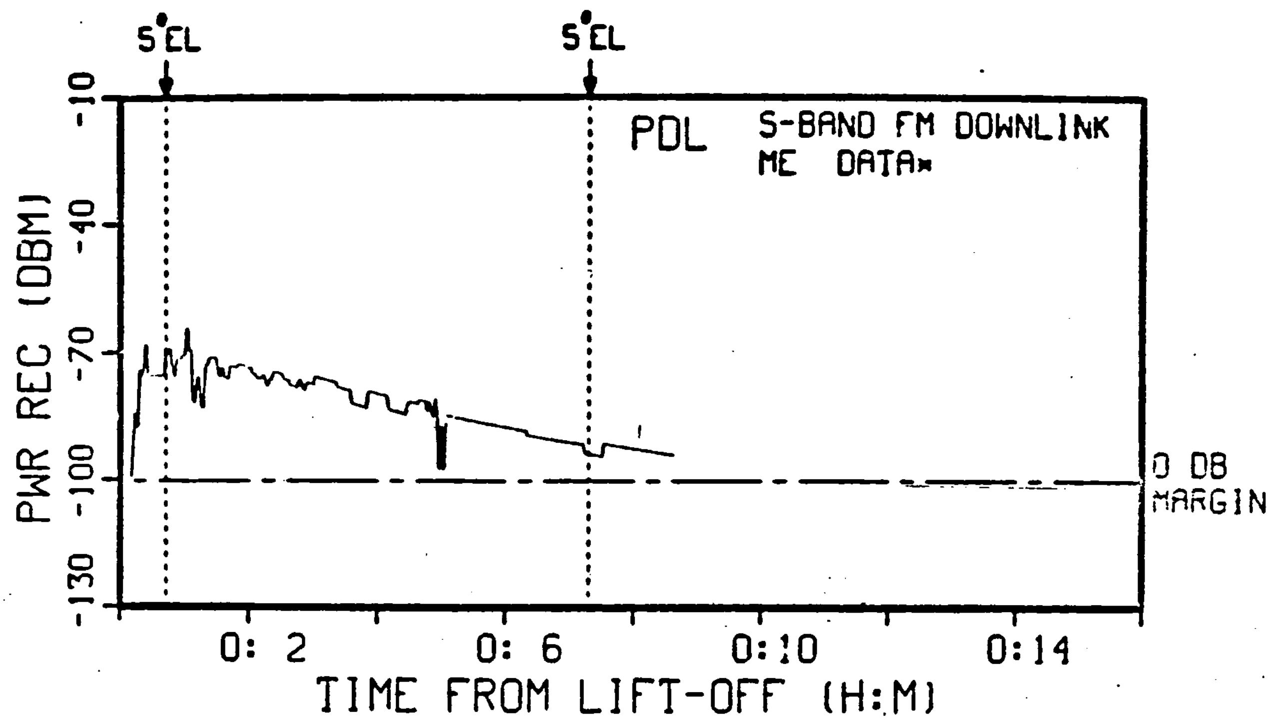


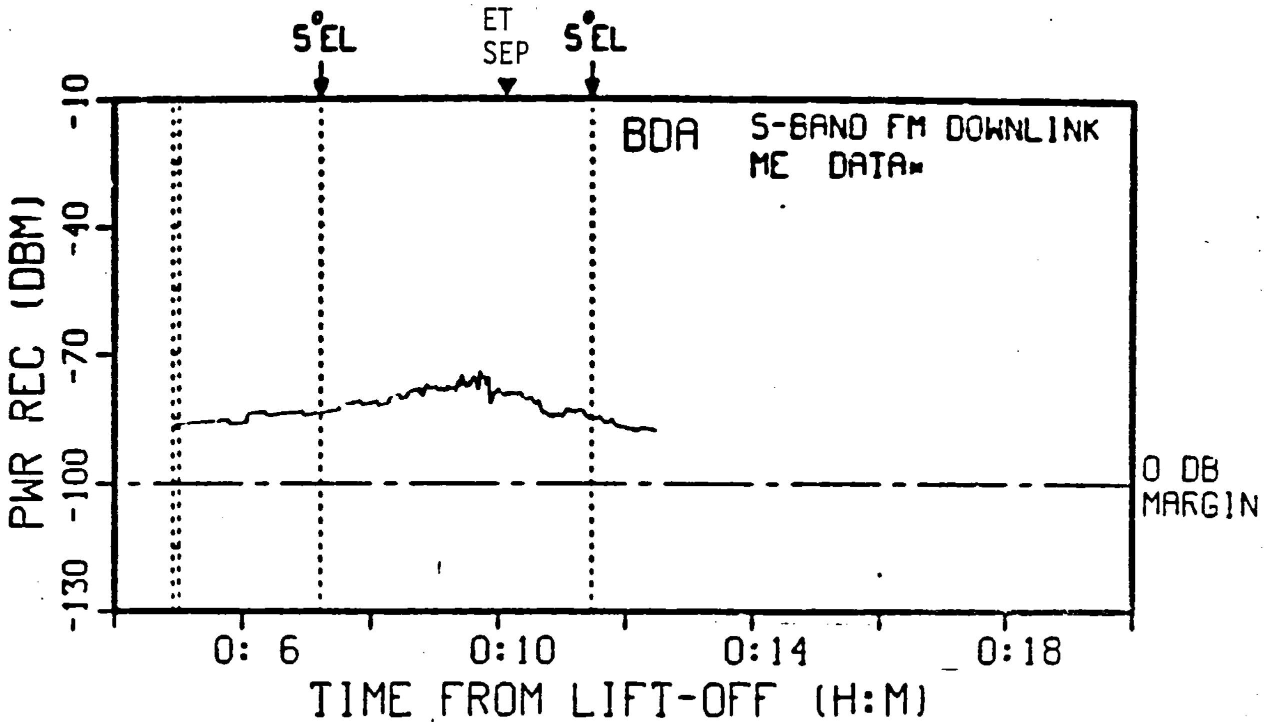
Figure 4-2.- Concluded.





*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 4-3.- Shuttle S-band FM downlink predicted RF signal power at MIL, PDL, and BDA during STS-2 AOA ascent (reference trajectory: Cycle 2).



*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 4-3.- Concluded.

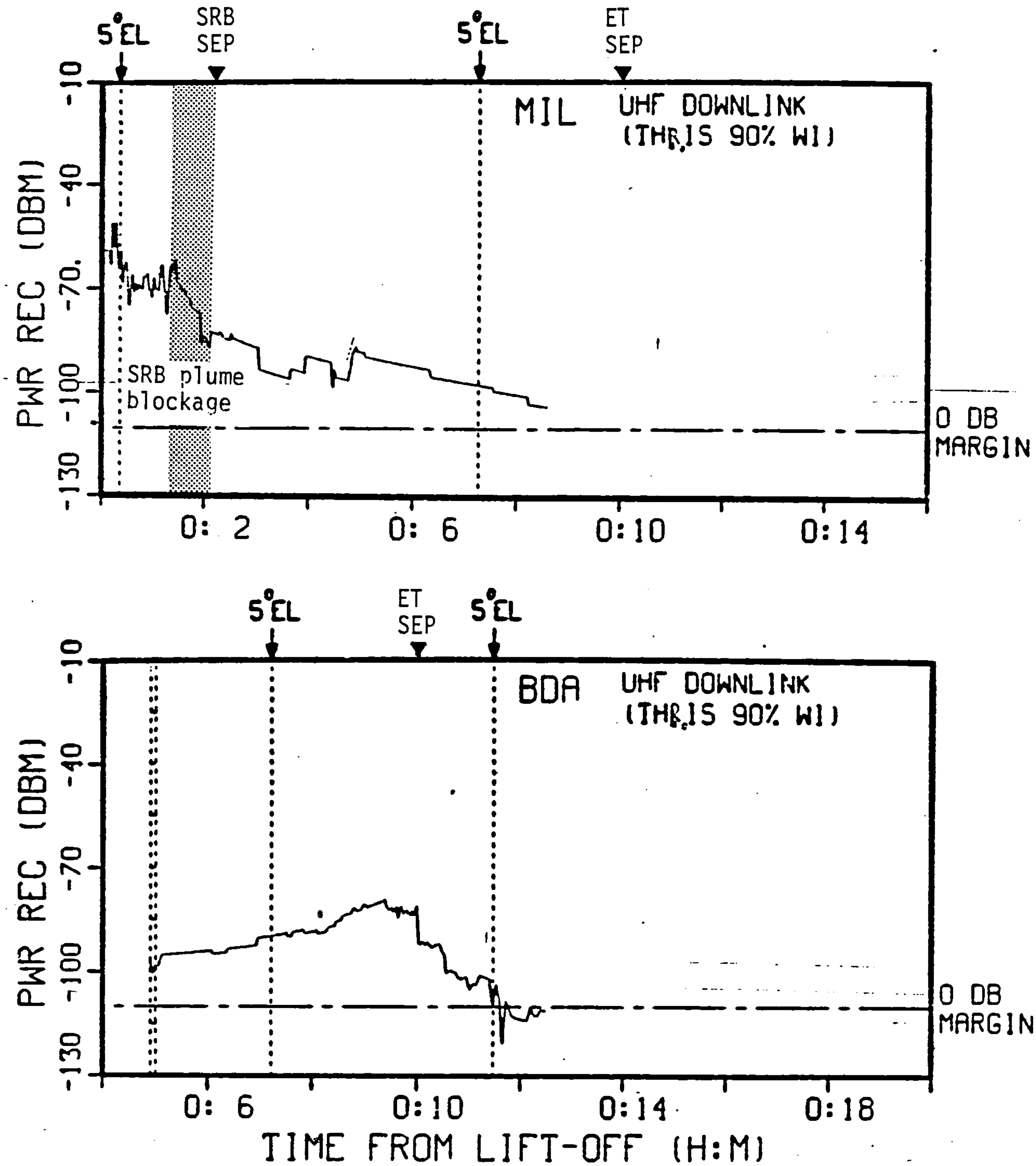


Figure 4-4.- Shuttle UHF voice downlink predicted RF signal power at MIL, and BDA during STS-2 AOA ascent (reference trajectory: Cycle 2).

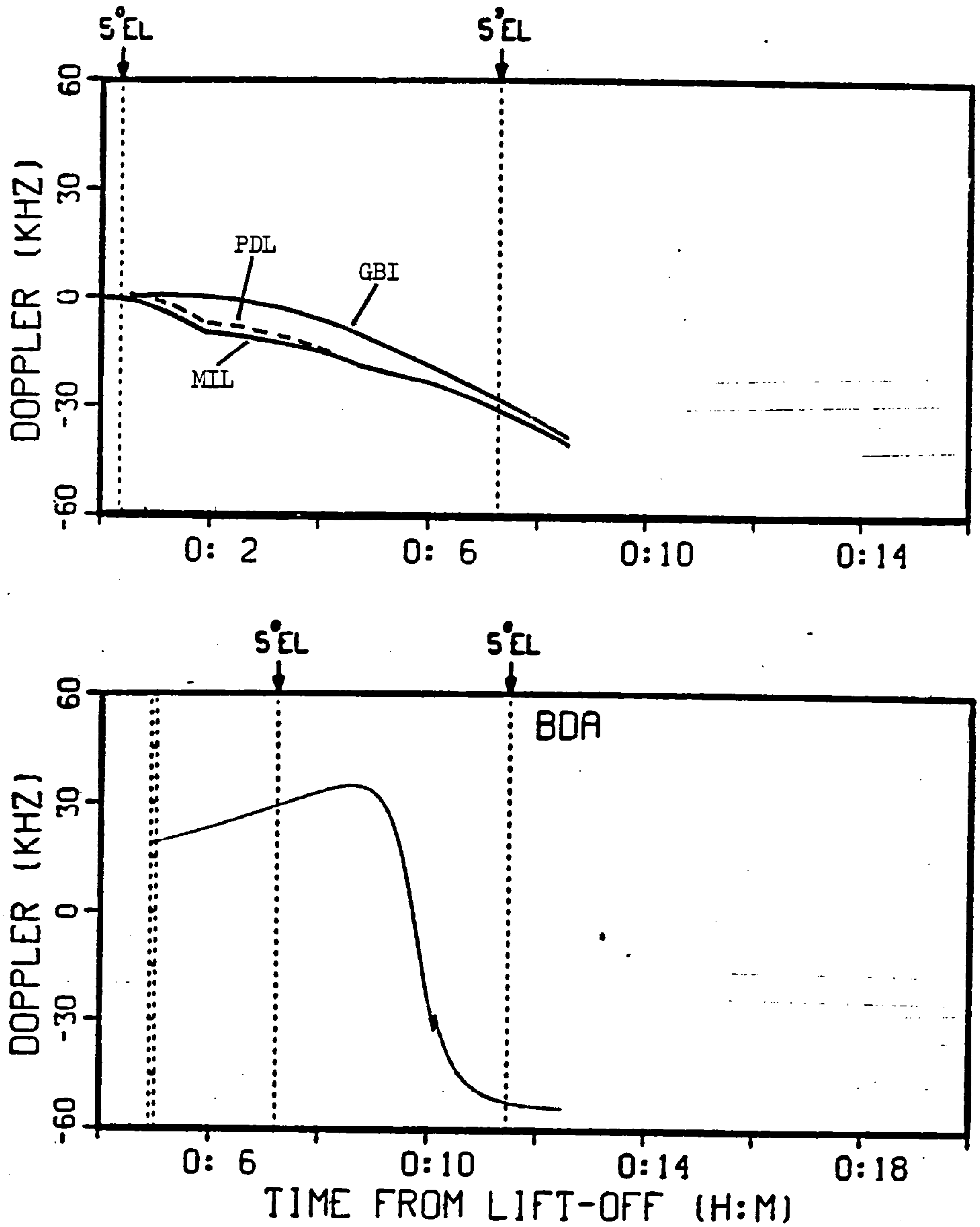


Figure 4-5.- AOA ascent Doppler, one-way (2287.5 MHz); MIL, PDL, GBI, and BDA (STS-2 Cycle 2 trajectory).

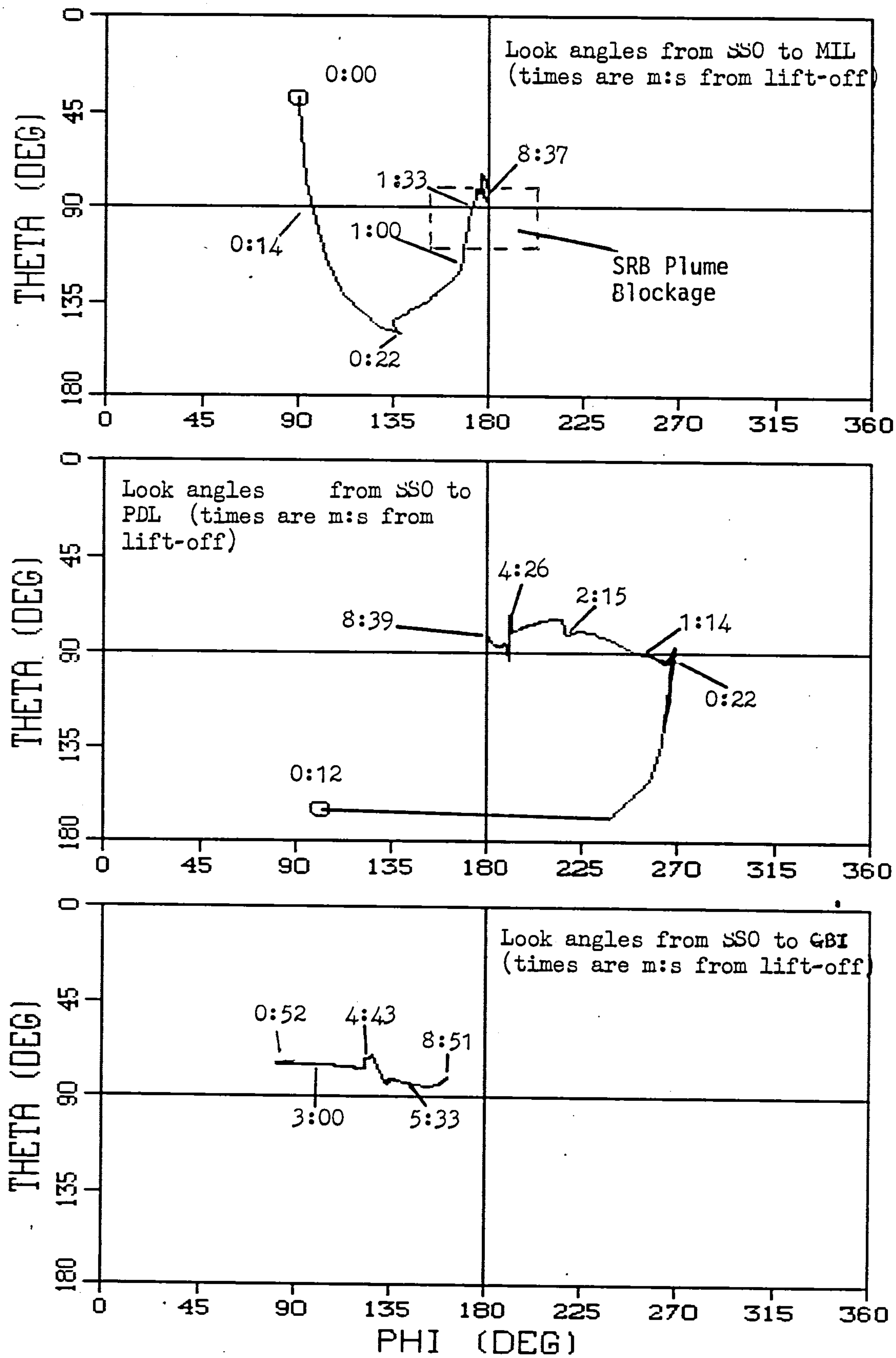


Figure 4-6.- Shuttle look angles to MIL, PDL, GBI and BDA during STS-2 AOA ascent (reference trajectory: Cycle 2).

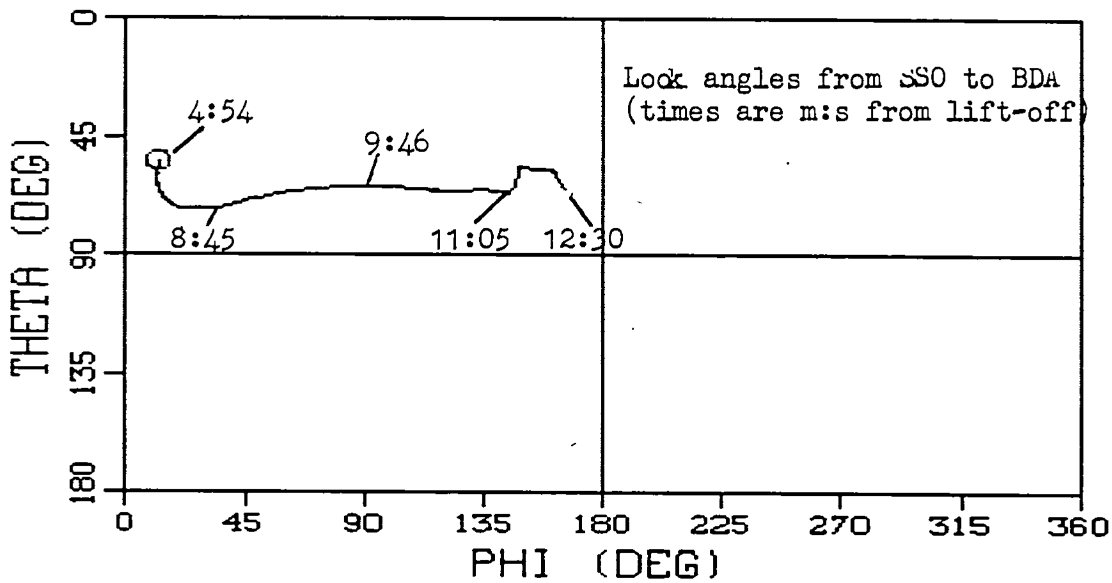
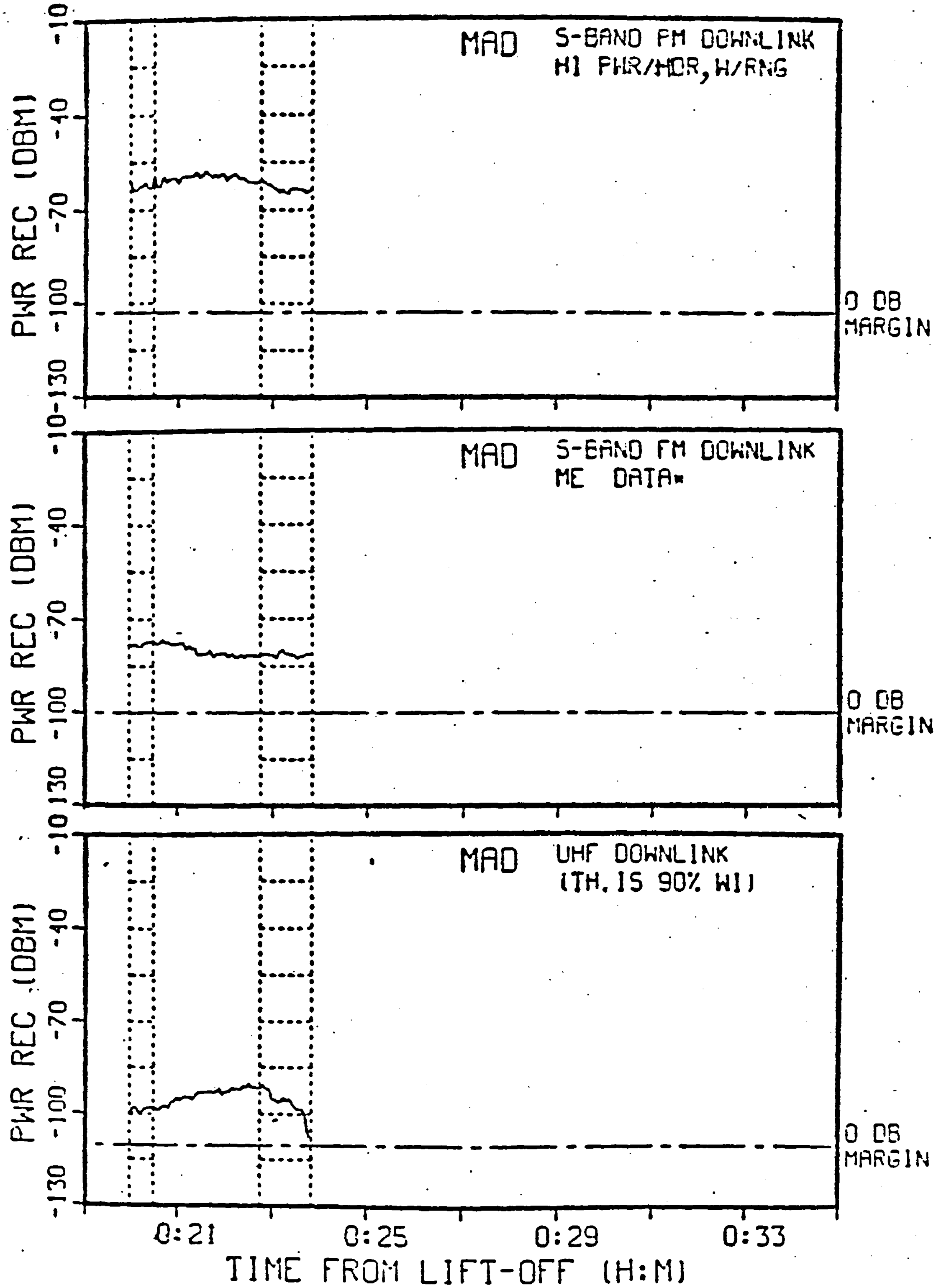
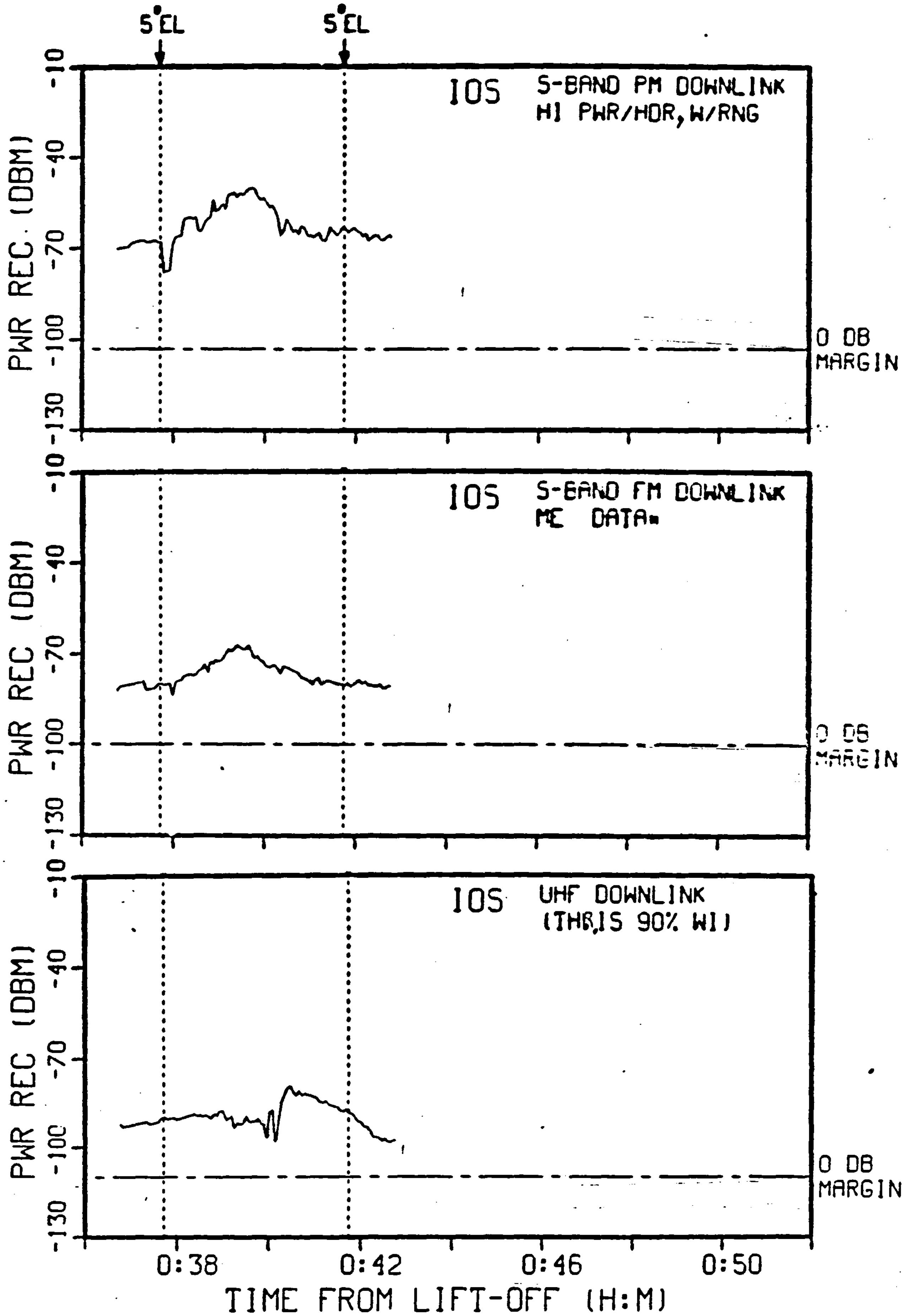


Figure 4-6.- Concluded.



*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 4-7.- Shuttle downlink predicted RF signal power at MAD during STS-2 AOA ascent (reference trajectory: Cycle 2).



*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 4-8.- Shuttle downlink predicted RF signal power at IOS during STS-2 AOA ascent (reference trajectory: Cycle 2).

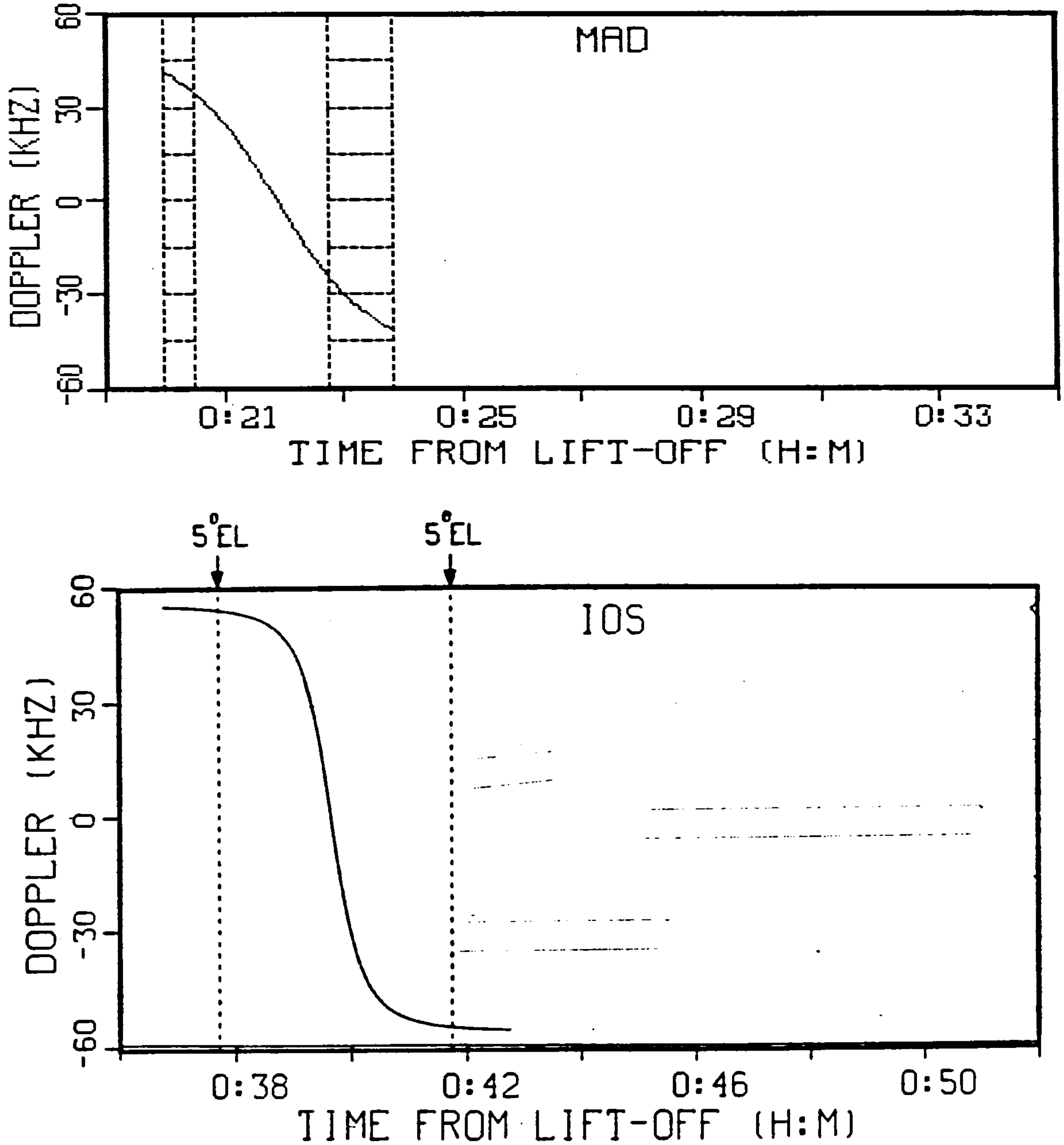


Figure 4-9.- AOA ascent Doppler, one-way (2287.5 MHz); MAD and IOS (reference trajectory: Cycle 2).

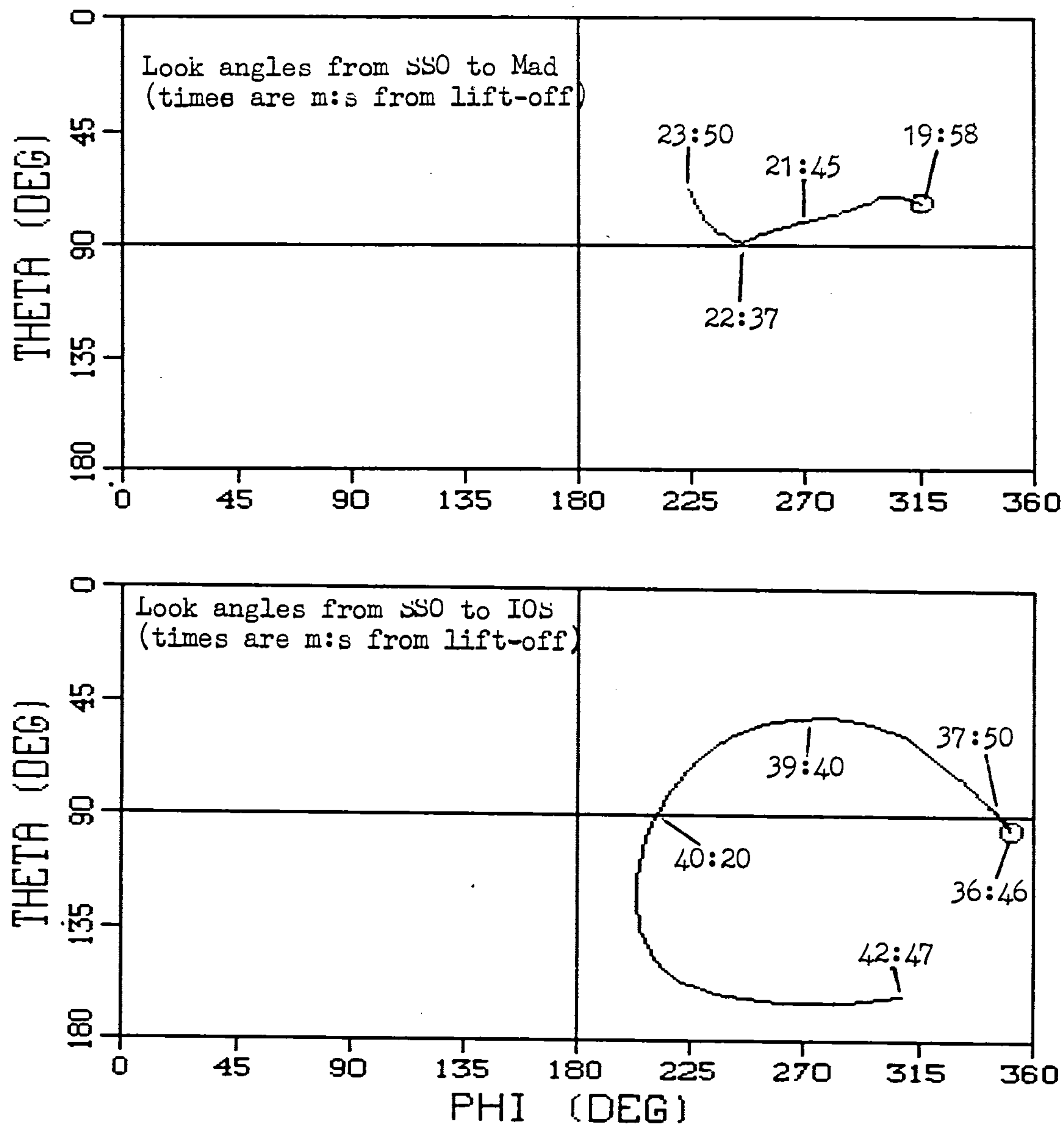


Figure 4-10.- Shuttle look angles to MAD and IOS during STS-2 AOA ascent
(reference trajectory: Cycle 2).

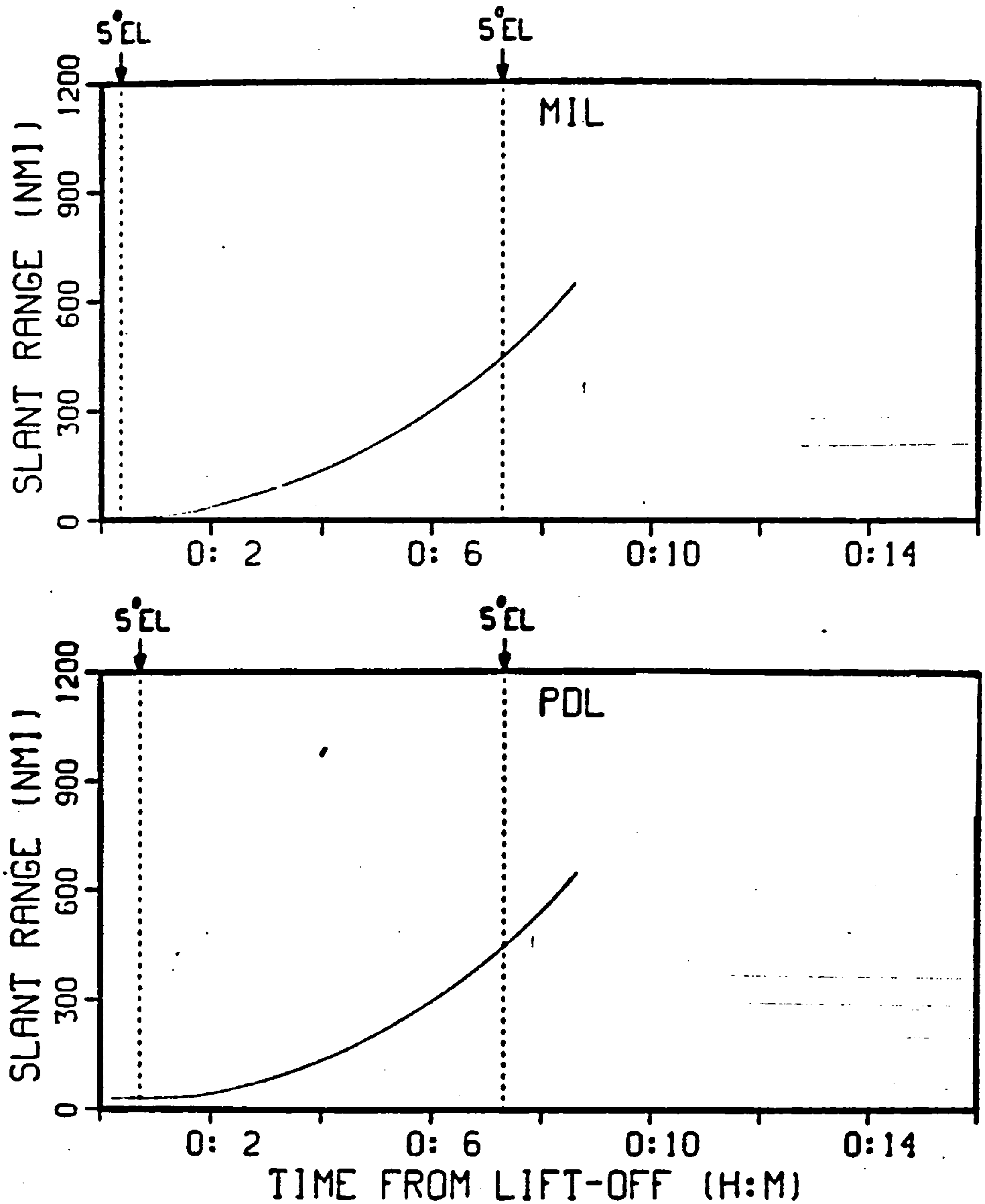
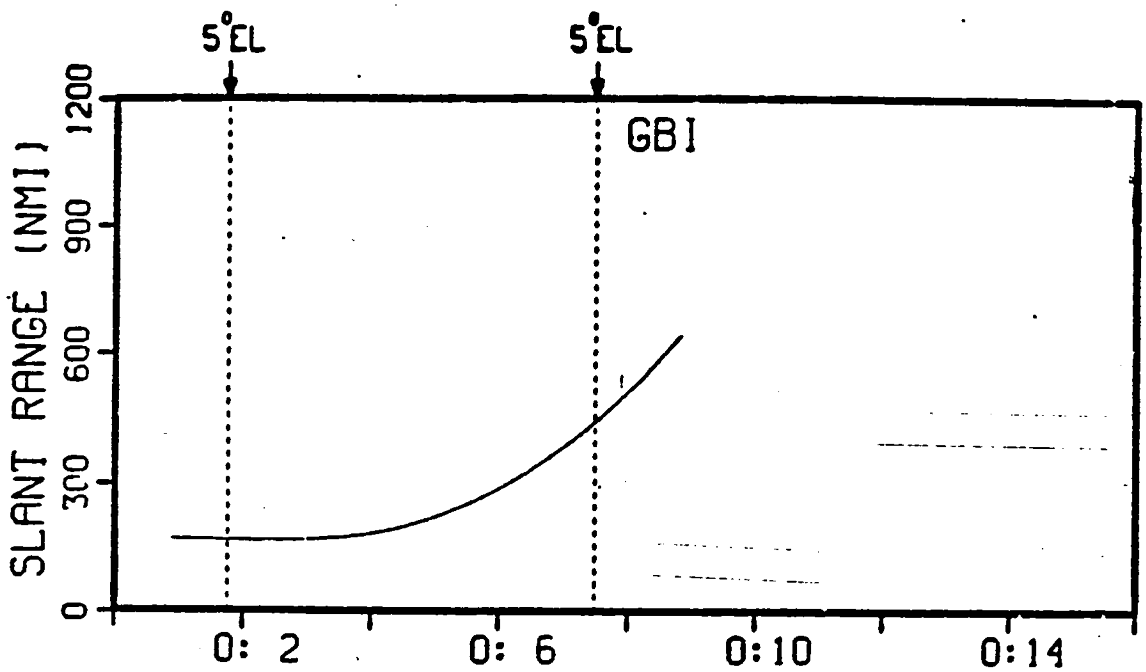


Figure 4-11.- Predicted slant range from the Shuttle to ground stations for STS-2 AOA (reference trajectory: Cycle 2).



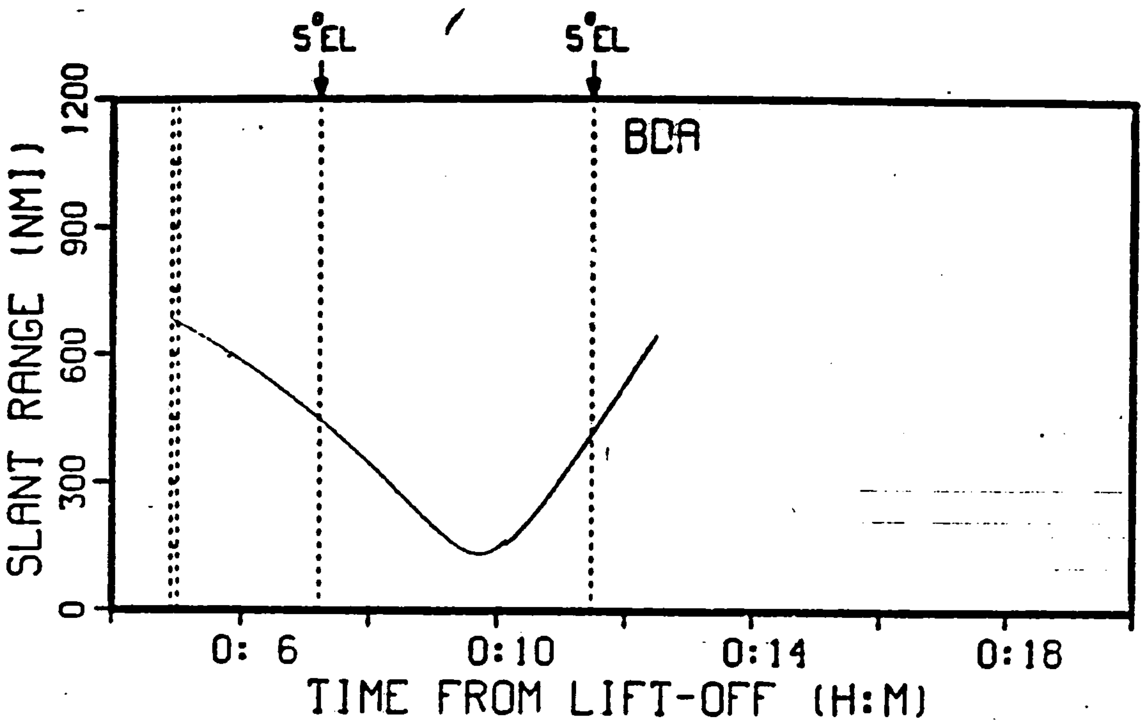


Figure 4-11.- Continued.

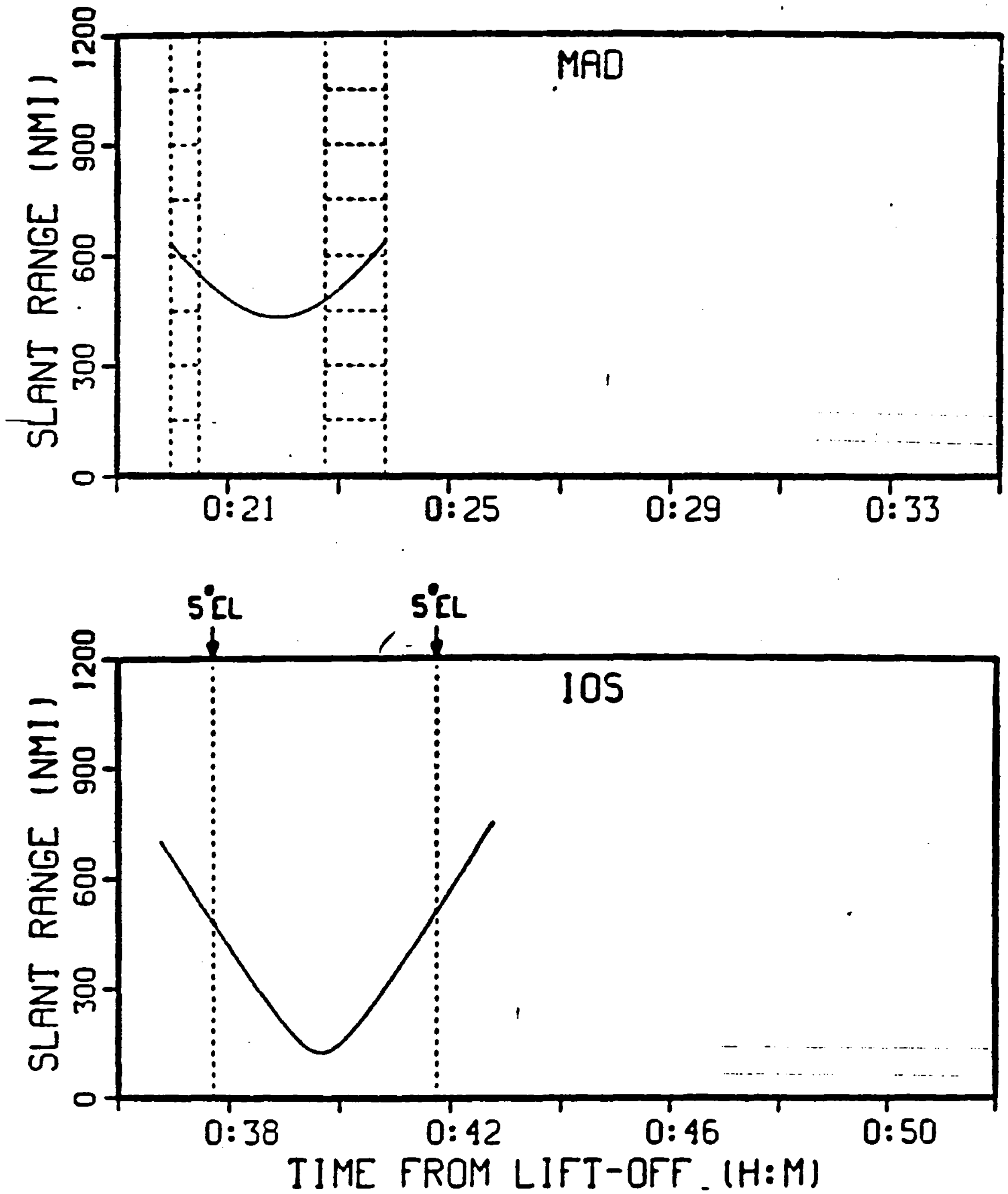


Figure 4-11.- Concluded.

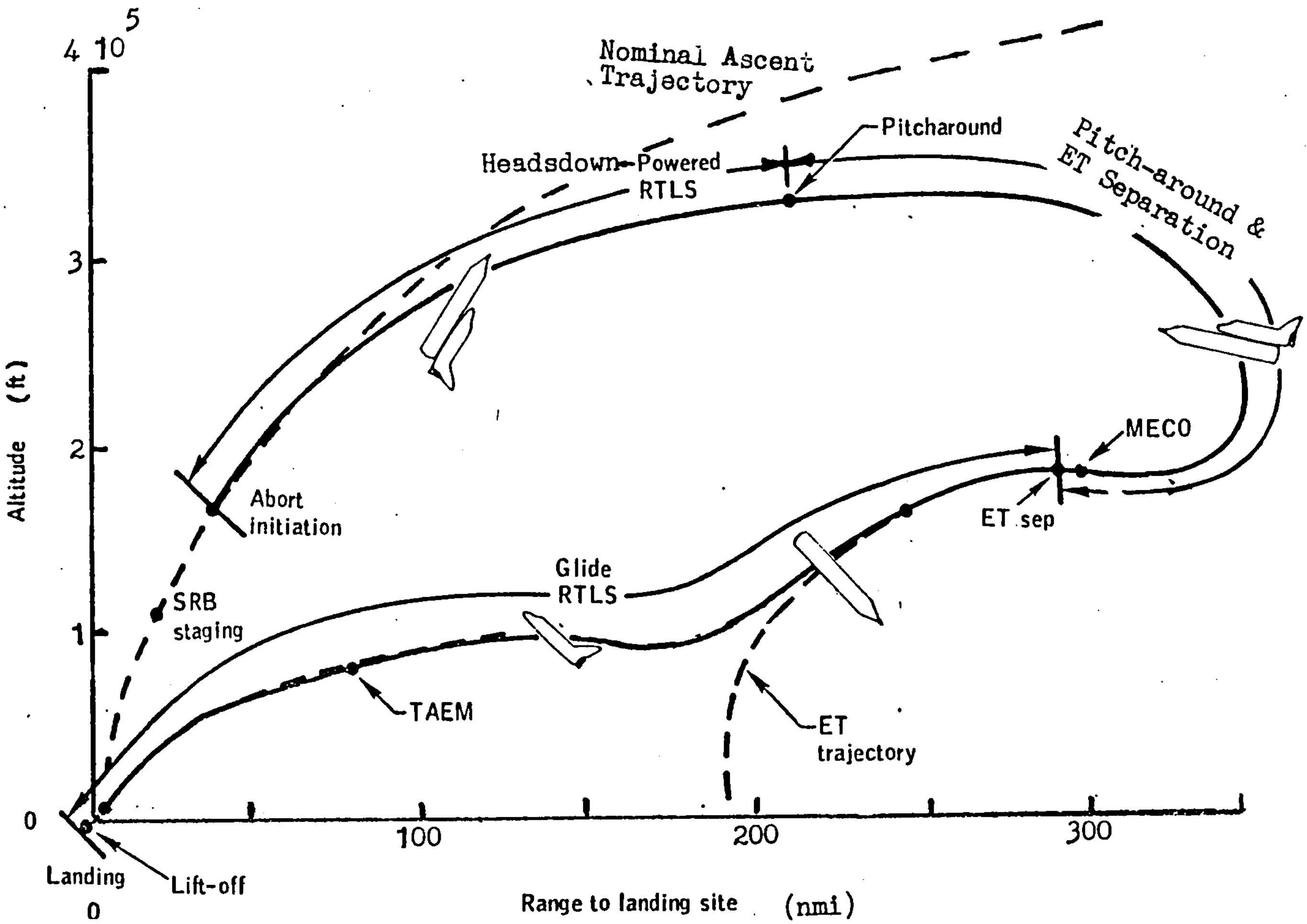


Figure 4-12.- Typical STS-2 RTLS abort scenario.

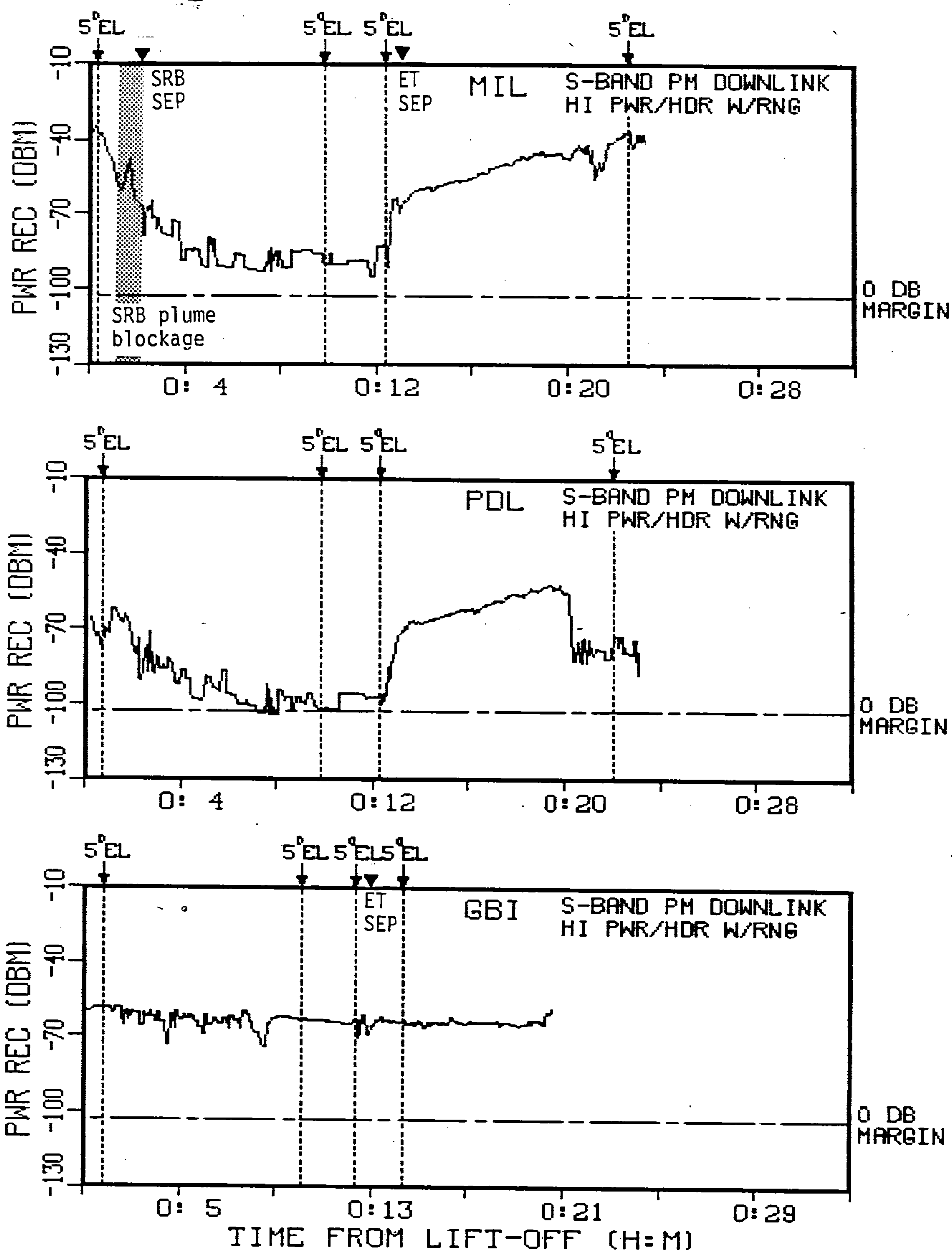
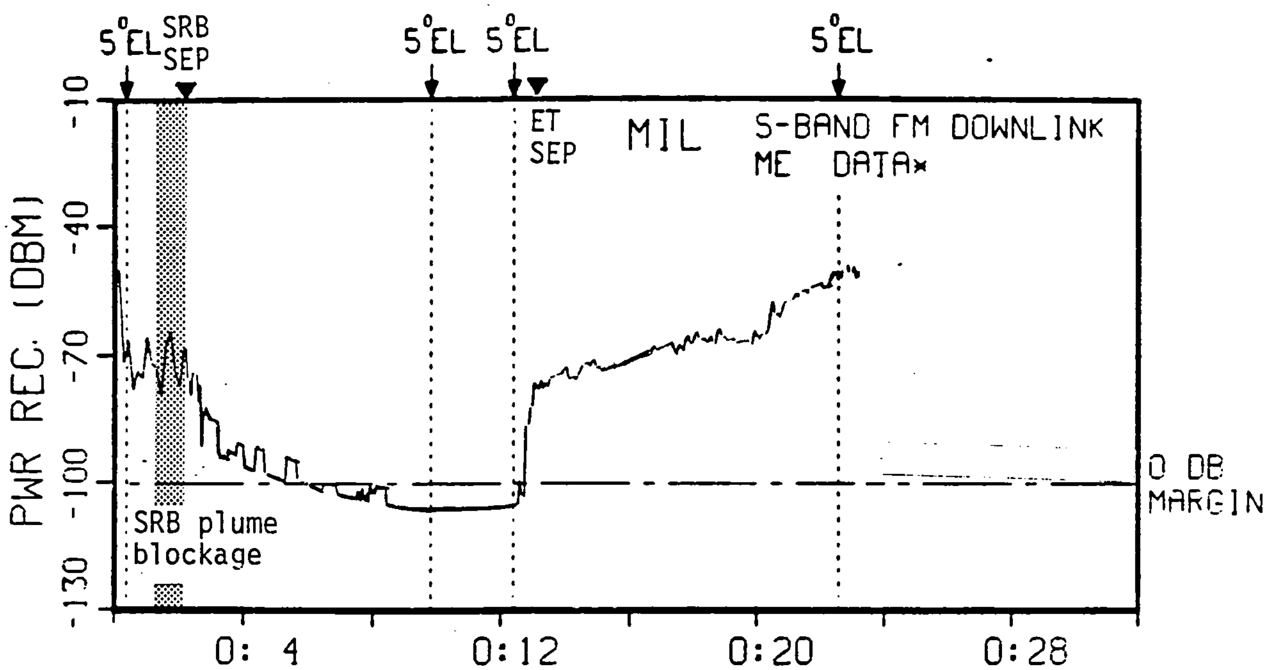
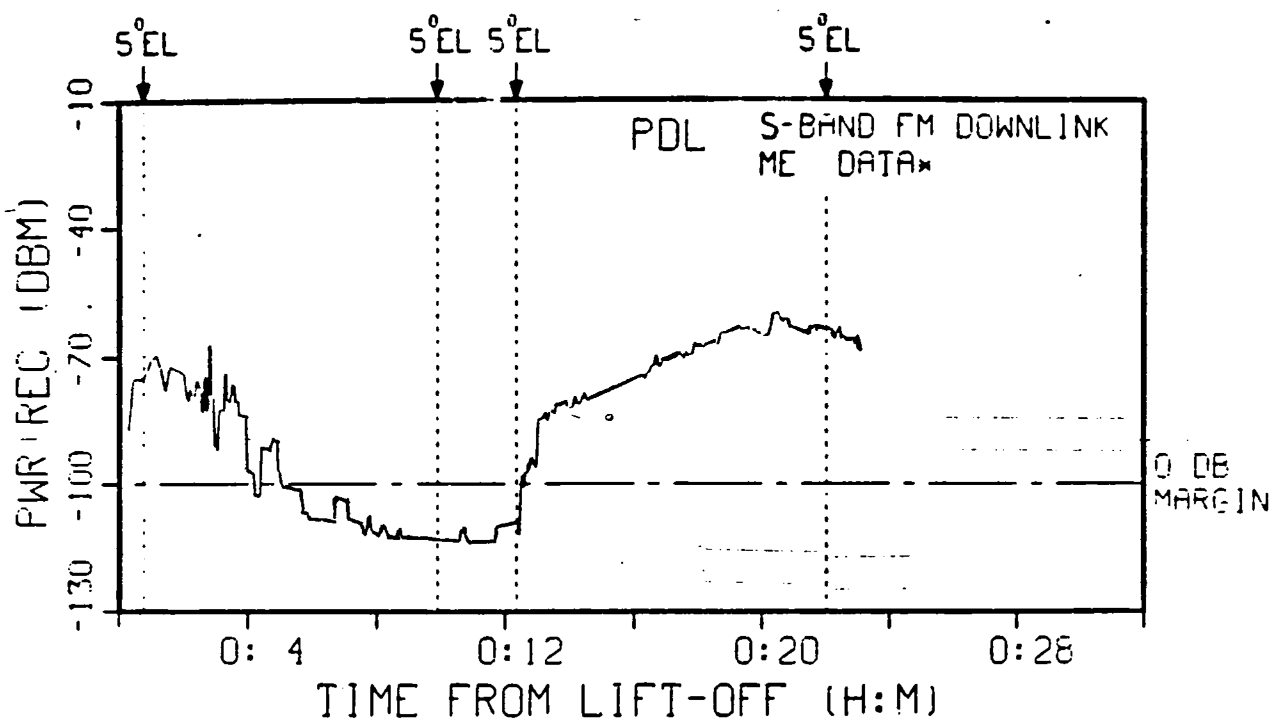


Figure 4-13.- Shuttle S-band PM downlink RF signal power at MIL, PDL, and GBI during STS-2 early RTLS (reference trajectory: Cycle 2).





*DFI link signal power is 1.8 dB less than ME data link; the threshold is the same for both.

Figure 4-14.- Shuttle S-band FM downlink RF signal power at MIL and PDL during STS-2, early RTLS (reference trajectory: Cycle 2).

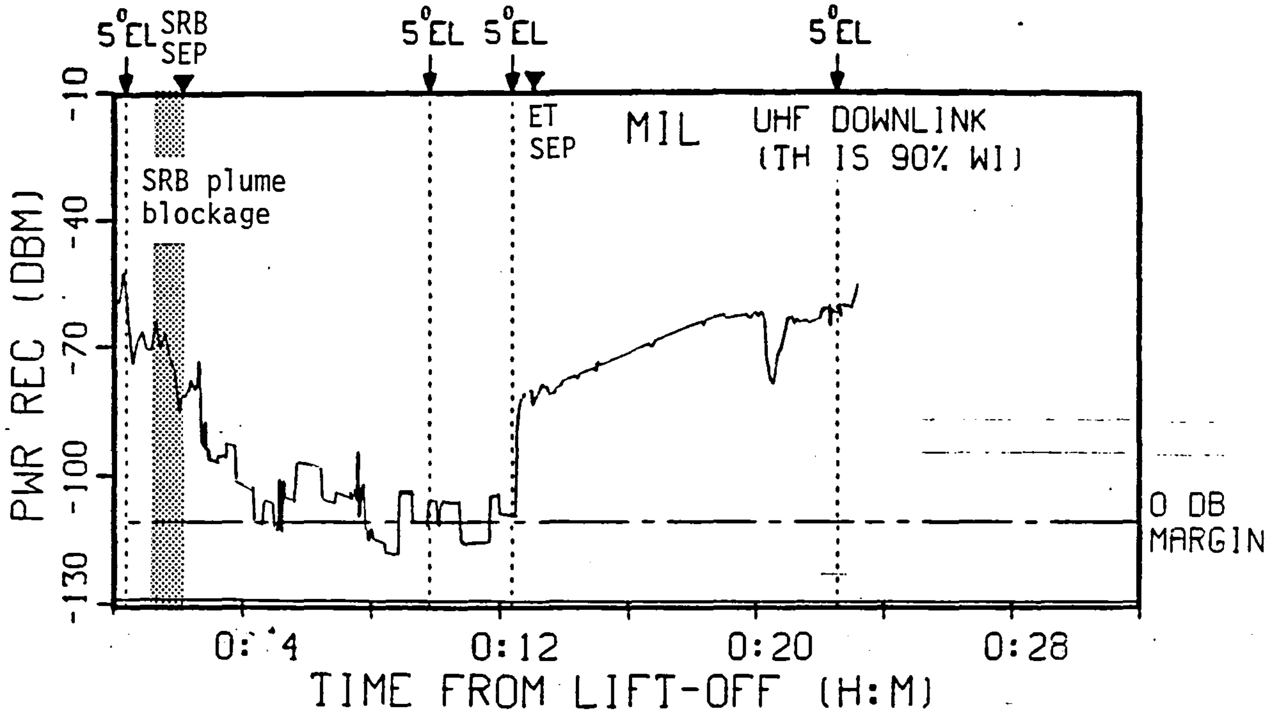


Figure 4-15.- Shuttle UHF voice downlink signal power at MIL during STS-2 early RTLS (reference trajectory: Cycle 2).

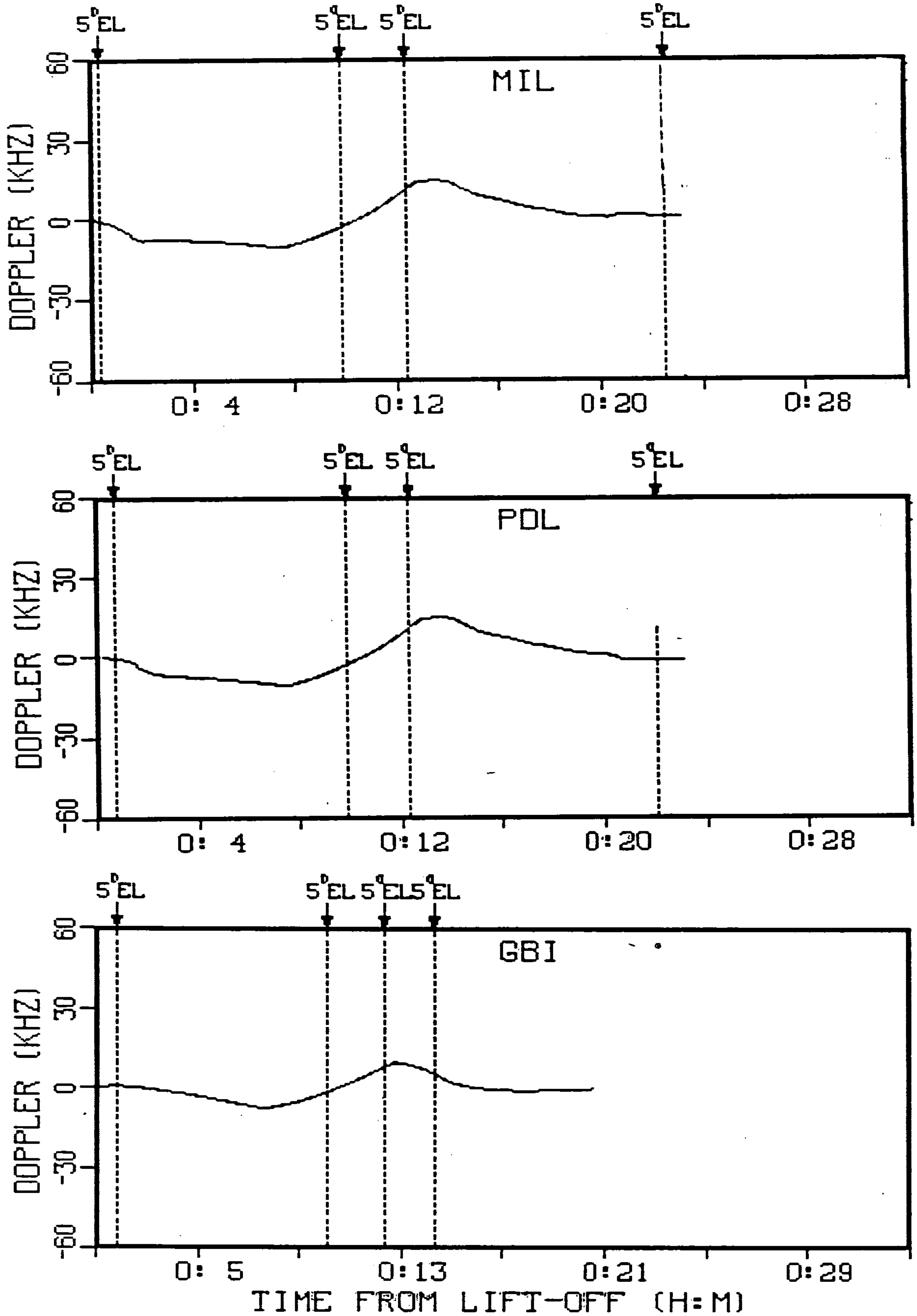


Figure 4-16.- Doppler for STS-2, early RTLS, one-way (2287.5 MHz), for MIL, PDL, and GBI (reference trajectory: Cycle 2).

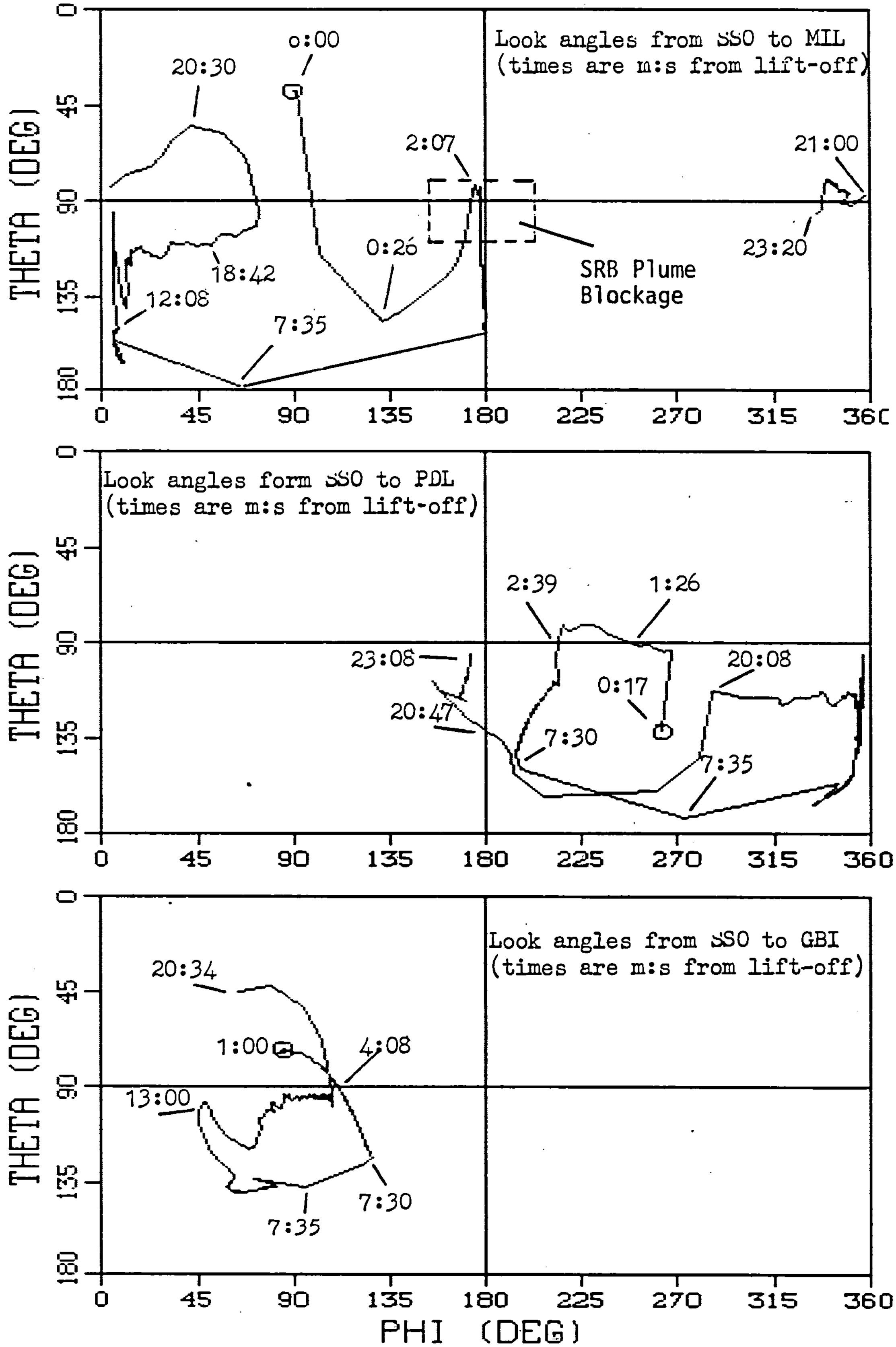


Figure 4-17.- Shuttle look angles to ground stations during STS-2, early RTLS (reference trajectory: Cycle 2).

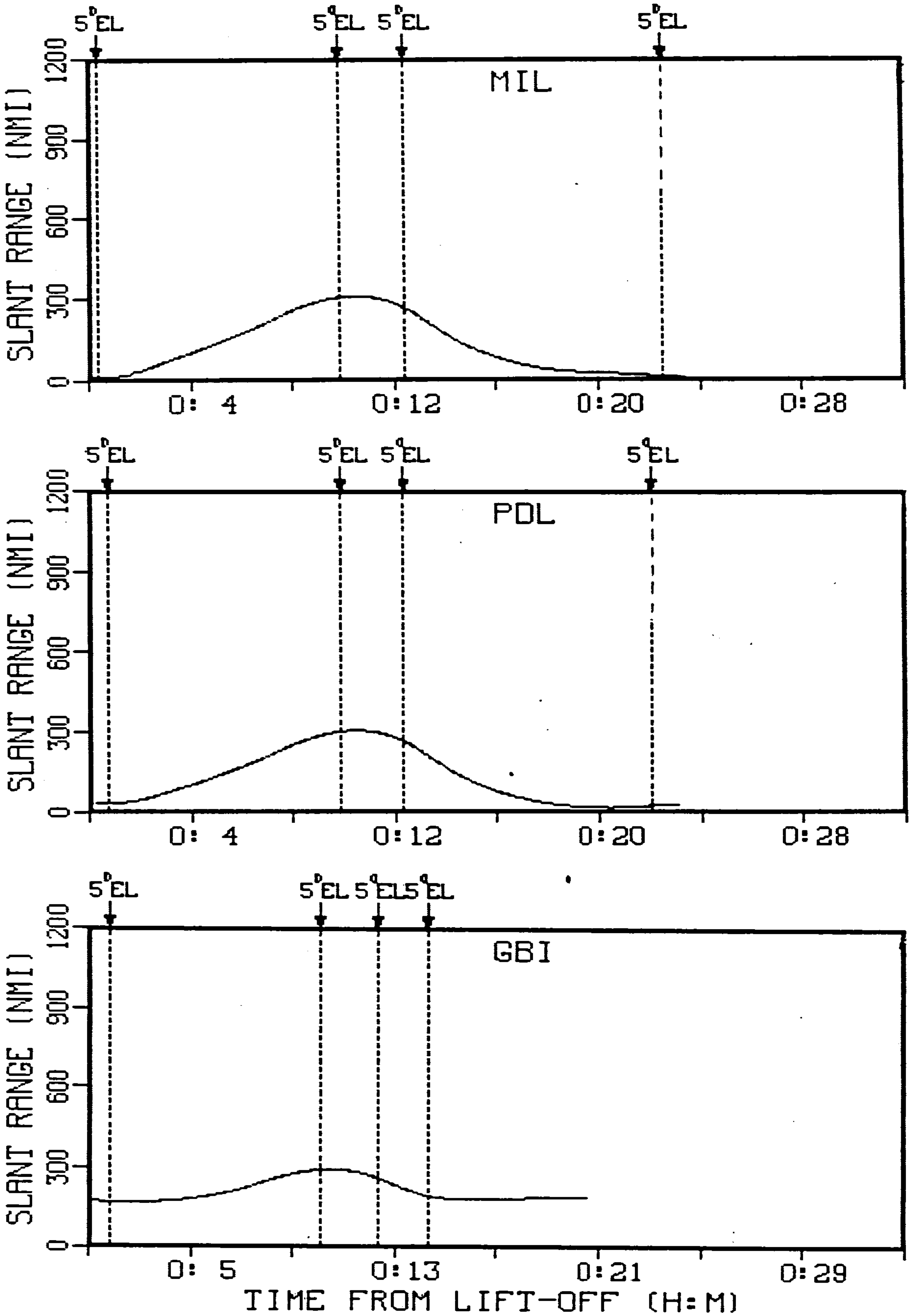


Figure 4-18.- Predicted slant range from the Shuttle ground stations for STS-2 early RTLS (reference trajectory: Cycle 2).

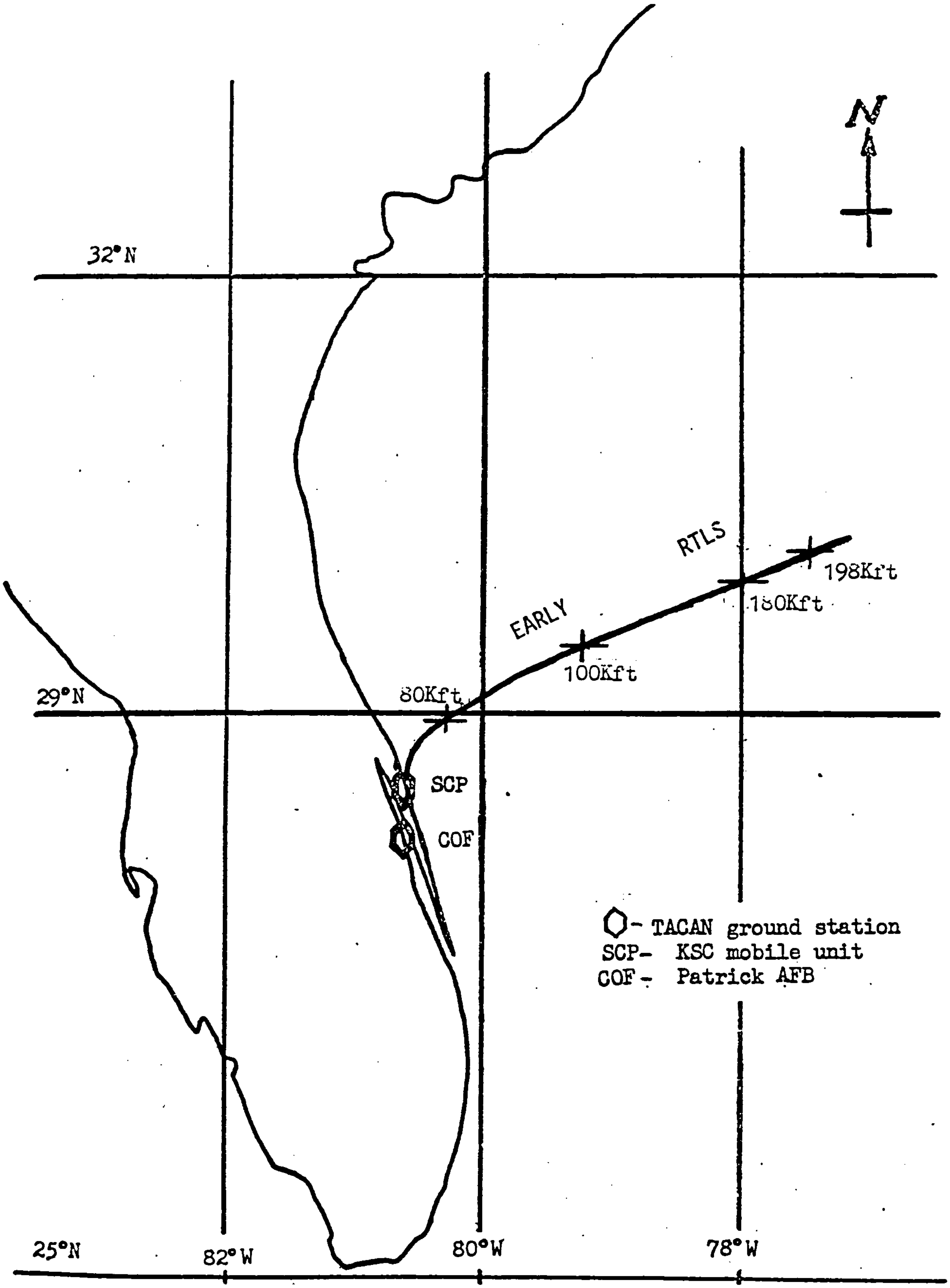


Figure 4-19.- TACAN ground station locations and the glide-to-landing phase of STS-2 early RTLS (reference trajectory: revised Cycle 2).

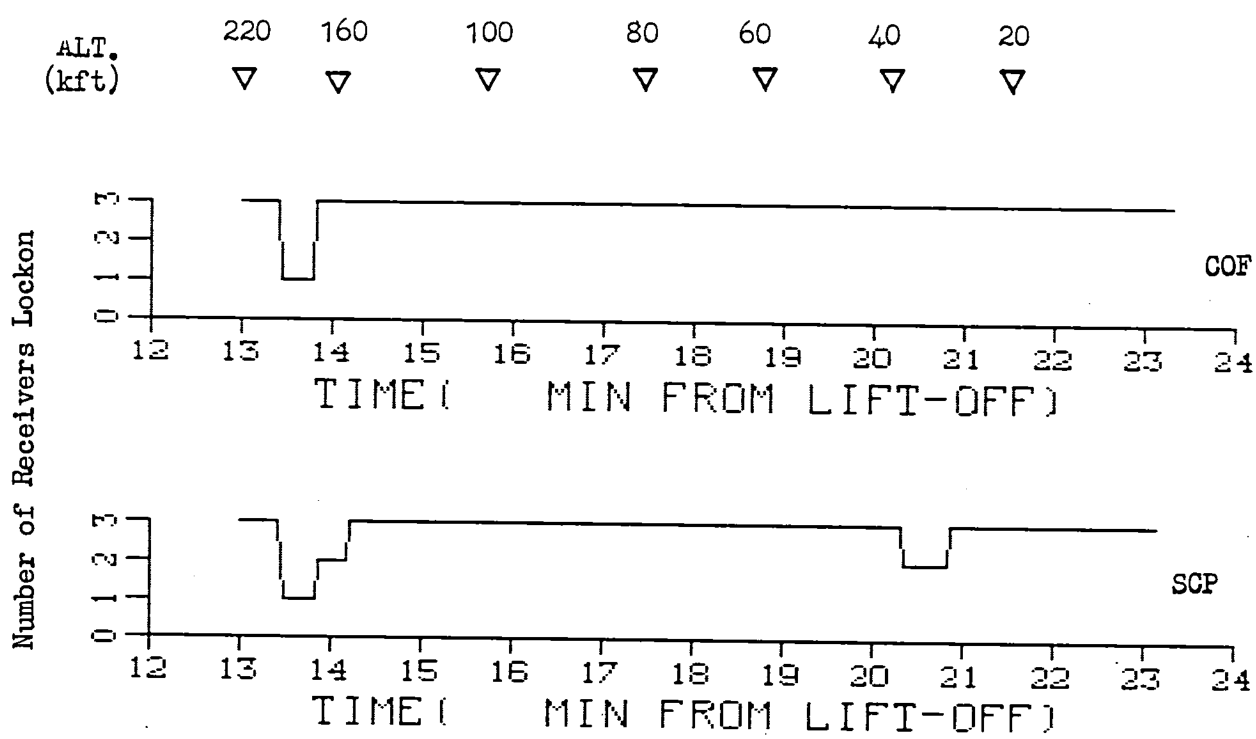


Figure 4-20.- Predicted TACAN lockon history for STS-2
early RTLS glide phase (reference trajectory: Cycle 2).

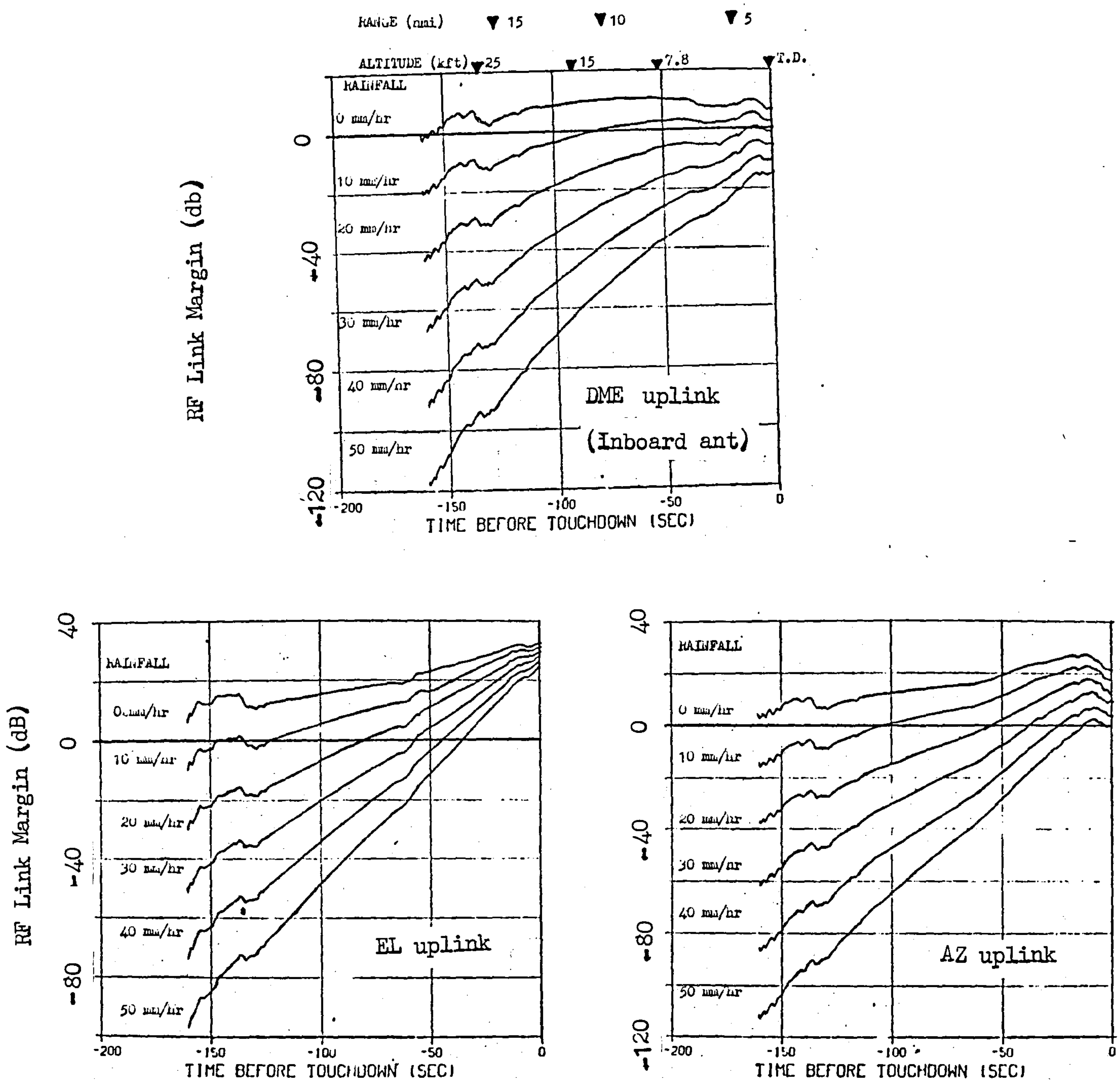


Figure 4-21.- RF link margin for the MSBLS DME, elevation, and azimuth channels (reference trajectory: Cycle 2).

5. SYSTEM DESCRIPTION: SHUTTLE ORBITER S-BAND COMMUNICATIONS AND TRACKING RF LINKS WITH GSTDN GROUND STATIONS

The following paragraphs provide a brief description of the Shuttle Orbiter S-band communications and tracking system and the S-band RF links with the GSTDN ground stations, as currently configured for support of STS-2, the second orbital Shuttle mission. The text is summarized in tabular form (tables 5-I, 5-II, 5-III, and 5-IV) at the end of the section to provide a convenient reference. Further details on the system can be obtained from reference 3.

5.1 Functions

The S-band direct communication links, between the orbiter and GSTDN ground stations (including the Air Force SCF Indian Ocean station, (IOS) perform several basic functions for the STS. In general, whenever line-of-sight exists, the SSO-GSTDN* S-band RF links will simultaneously and continuously provide the following functional capabilities: (1) the means for one or two independent real-time duplex digital voice channels between the Orbiter and ground stations, (2) the means for transmission of digital command data from ground stations to the Orbiter, (3) permit the transmission of data from the SSO to the GSTDN, including real-time, main engine data, real-time television, real-time analog or digital attached-payload data (not applicable to STS-2), real-time operational digital data, or the playback of recorded digital data (multiple real-time rates), and (4) ranging, Doppler tracking, and ground antenna angles, for the determination of Shuttle position and velocity.

5.2 Uplink Modes and the Uplink Modulation Process**

Direct uplink communications is required whenever there is line-of-sight between the GSTDN and the SSO. The link is a PM link, which may function in either a high or a low data rate transmission mode.

*There are some recent changes concerning the modulation index and the ground station support configuration during the ascent phase. These changes are pending and have not yet been reflected in the ICD (reference 3) and hence not in the ICD tables and figures in this section. They will be noted in the appropriate places in the text.

In the high-data-rate (HDR) mode the link will simultaneously provide two voice channels, one command channel, one synchronization channel, and one tone-ranging channel. Each voice channel is source-encoded by converting the analog audio signal into a 32-kbps digital sequence using a delta modulator, the 2.4-kbps command channel is encoded into a 6.4-kbps data sequence by a command encoder, and the 1.2-kbps synchronization pattern is time-division-multiplexed (TDM) with 0.4-kbps arbitrary fill data into a 1.6-kbps sync channel. The two voice channels, the encoded command channel, and the sync channel are TDM into a 72-kbps operational TDM signal, which is then converted from non-return-to-zero-level (NRZ-L) to bi-phase-L (Manchester II) format. If ranging is used, the GSTDN (not applicable to IOS) generates a range tone combination with components from 3.84 to 500 kHz which is transmitted by phase modulation (PM) of a 1.7-MHz subcarrier. The tone-modulated subcarrier is then frequency-division-multiplexed (FDM) with the 72-kbps operational TDM data signal, and the resulting FDM signal phase modulates the carrier* (2106.4 or 2041.9 MHz). Whenever the signal is received by the SSO receiver, a PM demodulator is used to recover the FDM signal. The 1.7-MHz tone modulated subcarrier and the receiver postdetection noise are separated from the FDM signal by a bandpass filter and are routed via the ranging turnaround channel to the downlink transmitter. The 72-kbps operational TDM data signal is detected by a bit synchronizer, and a frame sync demultiplexer identifies the synchronization pattern, resolves bit inversion, and separates the voice channels and the encoded command channel. The voice channels and command channel are routed to the voice delta demodulators and the command decoder.

For the case where ranging is not used, the 72-kbps operational TDM signal phase-shift-keys (PSK) the carrier. In the Orbiter receiver, a coherent PSK demodulator recovers the baseband TDM signal plus inadvertent receiver postdetection noise. The noise in the ranging turnaround channel is routed to

*There is a pending change which, during the ascent phase, requires MIL, PDL, and BDA to convolutionally encode the 72 kbps to 216 kbps and use a slightly higher modulation index (1.30 instead of 1.15). Also during acquisition and reacquisition, random noise will replace the 1/0 idle pattern in the voice channel. The above procedure will terminate and revert back to the normal HDR mode after the MIL and BDA passes.

the downlink transmitter and the operational TDM signal is processed as described in the previous paragraph.

When operating in the low-data-rate (LDR) mode, only one 24-kbps delta modulated voice channel is provided and the resulting operational TDM channel rate is 32 kbps instead of 72 kbps. The operation of the LDR mode is exactly the same as the HDR mode. The selection of the mode is independent of whether or not ranging is used. Figure 5-1 shows the functional interface configuration.

5.3 Downlink Modes and the Downlink Modulation Process

Direct downlink communication is required whenever SSO-GSTDN line-of-sight exists. The downlink communications employ both PM and FM links.

5.3.1 S-band PM Direct Downlink

As in the case with the PM uplink channel, the PM downlink may function in either an HDR mode or an LDR mode. The carrier is either a coherent turnaround of the S-band direct uplink carrier or a noncoherent carrier generated by an on-board auxiliary oscillator. Figure 5-2 shows the functional interface configuration as described in the following HDR and LDR-mode paragraphs.

HDR Mode: In the HDR mode, the PM link will simultaneously provide two voice channels, one real-time high-rate telemetry channel, and one tone-ranging channel. The two voice channels are each source-encoded with delta modulation of 32 kbps and are TDM with a 128-kbps telemetry channel to form a 192-kbps operational TDM signal. This operational TDM signal is then converted from the NRZ-L to the biphase-L (BIϕ-L) (Manchester II) format. If ranging is used (not applicable to IOS), the ranging turnaround channel from the uplink receiver contains the received tone-modulated 1.7-MHz subcarrier plus bandpass-filtered system noise. If ranging is not used, the ranging turnaround channel contains only noise. Whenever the coherent downlink frequency is used, the ranging turnaround channel is FDM with the 192-kbps

operational TDM signal, and the resulting FDM signal phase-modulates the carrier. The coherent turnaround downlink carrier frequency is 240/221 times the received uplink carrier frequency. Whenever the auxiliary oscillator is used, the 192-kbps operational data, without ranging, phase-modulates the carrier. The auxillary oscillator downlink carrier frequency is 2287.5 or 2217.5 MHz. On the ground, a PM receiver recovers the downlink carrier modulating signal, and the 192-kbps operational TDM signal is detected by a bit synchronizer. If ranging is used, the 1.7-MHz tone-modulated ranging subcarrier is also recovered, demodulated by a subcarrier PM demodulator, and sent to a range-tone processor where range is determined. The ground station receiver also provides two-way Doppler extraction.

LDR Mode: The LDR mode provides only one delta-modulated voice channel at the rate of 32 kbps, plus a low-rate telemetry channel at the rate of 64 kbps. The resulting operational TDM channel rate is 96 kbps instead of 192 kbps. The operation of the LDR mode is the same as the HDR mode.

5.3.2 S-band FM Direct Downlink

There are two FM downlinks, an operational instrumentation (OI) link at 2250 MHz and a developmental flight instrumentation (DFI) link at 2205 MHz. The OI link provides the following wideband data: (only one at a time; the first will be used during ascent)

a. Three independent 60 kbps digital-data channels for transmitting real-time main engine data.

b. Real-time television (either color or black and white)

c. Real-time attached payload data, either analog (300 Hz to 4 MHz) or digital (200 bps to 5 Mbps). (Not applicable for STS-1)

d. Playback digital data from the OI recorder. (The several options for transmitting this data are discussed in detail in ref. 3.)

The DFI link provides transmission of one 128-kbps digital telemetry channel and 15 FM subcarrier channels.

For the OI link, in the SSO FM signal processor the three real-time ME data channels PSK-modulate three subcarriers at 576 kHz, 769 kHz, and 1024 kHz. These are then frequency-division-multiplexed into a single analog signal. The FM signal processor accepts one of its input analog or digital data signals, or the FDM ME data signal and FMs the selection onto the link carrier (2250 MHz). At the ground station, the carrier modulating signal is recovered by an FM wideband receiver and demodulator. The ground station processor routes the postdetection signal as required. Figure 5-3 shows the functional interface configuration for the FM OI link.

The DFI link uses a separate wideband FM transmitter (carrier frequency 2205 MHz) to transmit the DFI telemetry. The DFI telemetry consists of 16 information channels -- one 128-kbps DFI digital telemetry channel and 15 FM subcarrier channels. The 128-kbps DFI digital telemetry data in a BIϕ-L (Manchester II) format PSK a 1.024-MHz subcarrier which is then FDM with the 15 FM subcarrier channels. The resulting composite signal is used to frequency modulate the 2205 MHz carrier.

At the ground station, a wideband FM receiver in series with a 1.024-MHz PSK subcarrier demodualtor is used to convert the DFI RF signal to the 128-kbps baseband signal which is then detected by the bit synchronizer. The 15 FM subcarrier data channels (at the output of the FM receiver), are sent through a low pass filter. The 128-kbps PCM, the FM subcarrier data channels, receiver AGC, IRIG time, and voice annotation will all be recorded for shipment to JSC. Figure 5-4 shows the functional interface configuration for this link.

5.4 RF Characteristics

5.4.1 Link Configuration Characteristics

The main characteristics of the S-band direct communications links are summarized in tables 5-I through 5-IV. The following notes apply to these tables:

a. Bit rates and subcarrier and carrier frequencies are specified at the link transmitter and will differ at the receiver by the transmission-to-

receiver Doppler shift. The error tolerances are also specified at the transmitter and are the errors which will be accommodated by the receiving system in addition to Doppler shift.

b. The minimum transmitted effective isotropic radiated power (EIRP) is the required minimum signal EIRP towards the receiver and includes the transmitter RF signal power, transmitting circuit losses, and transmitting antenna gain towards the receiver -- narrowbeam axial gain plus pointing loss (uplink), or widebeam minimum gain over a specified coverage region which includes the receiver (downlink).

c. The minimum G/T (receiving antenna gain-to-system-noise-temperature ratio) is the required minimum receiver G/T and includes the receiving antenna gain and the receiving system noise temperature both referenced via the receiving circuit losses to a common RF point.

d. The GSTDN EIRP and G/T values are specified for each GSTDN antenna type that may be used for the link. The minimum G/T value for a particular GSTDN station is based on the system temperature with the antenna pointing 3° above the land mask. Since the minimum G/T value differs somewhat from station to station, the minimum G/T value given here is a nominal value for the network of GSTDN stations.

e. P_{rec}/N_0 is the received RF signal-power-to-noise-spectral-density ratio resulting from the transmitted signal EIRP toward the receiver, the space loss, the transmitting and receiving antennas' polarization mismatch, the receiving antenna pointing loss, and the receiving system G/T. The required P_{rec}/N_0 value is the threshold or zero-margin value for which the receiver system will deliver the required performance for acquisition, data quality, or whatever the case may be.

5.4.2 RF Acquisition Sequence*

This section gives the performance requirements for S-band PM RF carrier acquisition and describes the operational sequences for establishing two-way

*This sequence is only for onorbit and entry support. Pending changes will require that an "automatic acquisition" procedure be used during the ascent phase, for MIL, PDL, and BDA. This change is being incorporated into reference 3.

RF communications between the SSO and a GSTDN station.

The GSTDN and SSO will have the following functional capabilities and performance characteristics in order to support the acquisition sequences:

a. The GSTDN transmits at the uplink carrier frequency, without modulation. The uplink carrier modulation can be manually switched on and off at any time with no accompanying carrier frequency transient.

b. The SSO receiver is sweeping and will acquire the unmodulated uplink carrier within ±75 kHz of the nominal carrier frequency with an acquisition probability of 0.9 or greater in 6 seconds if the received carrier-power-to-noise-spectral-density ratio is as specified in table 5-I. When the receiver is tracking an unmodulated carrier and the modulation is switched on, the carrier tracking loop will not lose lock while settling to modulated carrier tracking. Upon loss of carrier lock for any reason, the receiver automatically switches to the carrier acquisition mode.

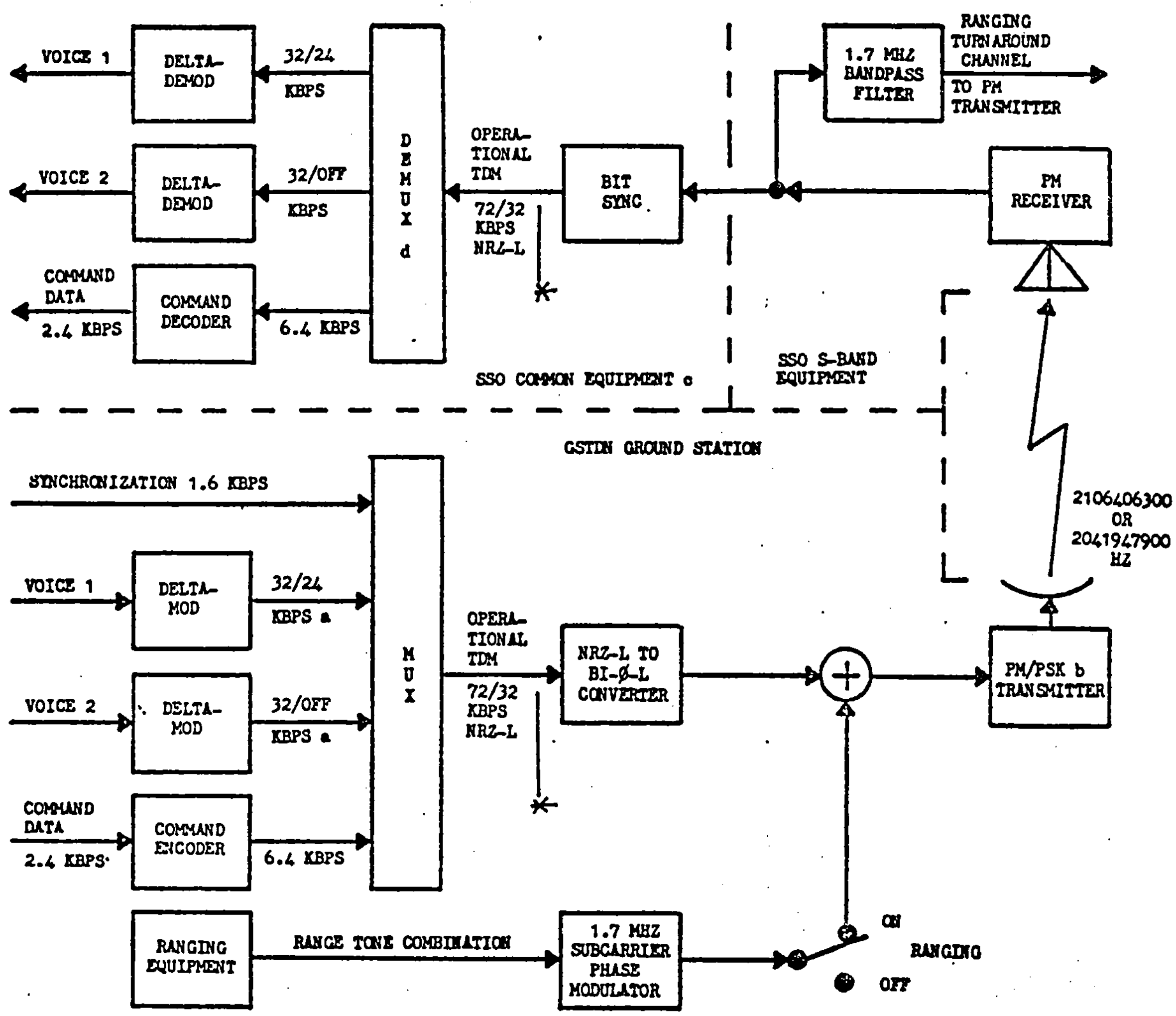
c. The SSO receiver carrier tracking lock status and the SSO uplink data frame sync-lock status are included in the downlink telemetry.

d. While the SSO receiver is in the carrier acquisition mode, the SSO transmitter downlink carrier frequency is derived from the auxiliary oscillator. While the SSO receiver is in the carrier tracking mode, the SSO transmitter downlink carrier frequency is coherently derived from the received uplink carrier frequency with a turnaround frequency ratio of 240/221. The transmitter switch from auxiliary oscillator to coherent turnaround occurs about 0.9 second after receiver carrier lock occurs. The transmitter switch from coherent turnaround to auxiliary oscillator occurs immediately when the receiver loses carrier lock.

   The GSTDN receiver will acquire a modulated downlink carrier within ±200 kHz of the nominal carrier frequency with an acquisition probability of 0.9 or greater in 3 seconds if the received carrier-power-to-noise-spectral-density ratio is as specified in table 5-II. With the SSO

transmitter on auxiliary oscillator, the GSTDN received carrier offset is the oscillator frequency error plus one-way Doppler. With the SSO transmitter on coherent turnaround, the GSTDN received carrier offset is the two-way Doppler. When the SSO transmitter switches from one frequency source to the other, the GSTDN received carrier frequency will have a step which may cause the GSTDN receiver to lose carrier lock. Upon loss of carrier lock for this or any reason, the GSTDN receiver automatically switches to the carrier acquisition mode.

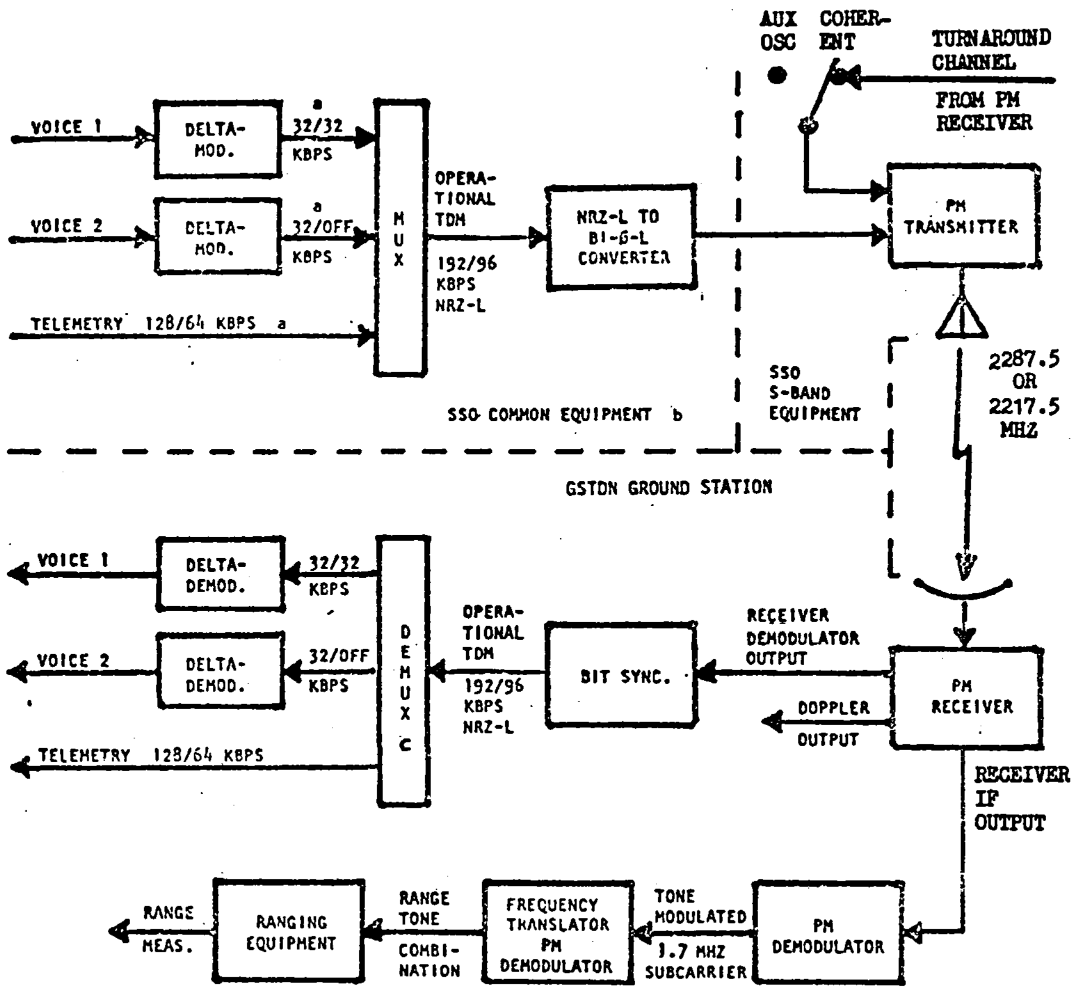
e. For handover from GSTDN Station A to GSTDN Station B, Station A will terminate transmission and simultaneously station B will begin an initial two-way acquisition sequence.



a HIGH DATA RATE/LOW DATA RATE
b RANGING ON/OFF
c SAME EQUIPMENT USED FOR S-BAND AND Ku-BAND FORWARD RELAY LINKS
d FRAME SYNC USES 1.6 KBPS SYNCHRONIZATION CHANNEL

*Pending change will require using the convolutional encoder in the GSTDN and the Viterbi decoder at the SSO.

Figure 5-1.- GSTDN/IOS-to-SSO S-band direct uplink functional configuration.

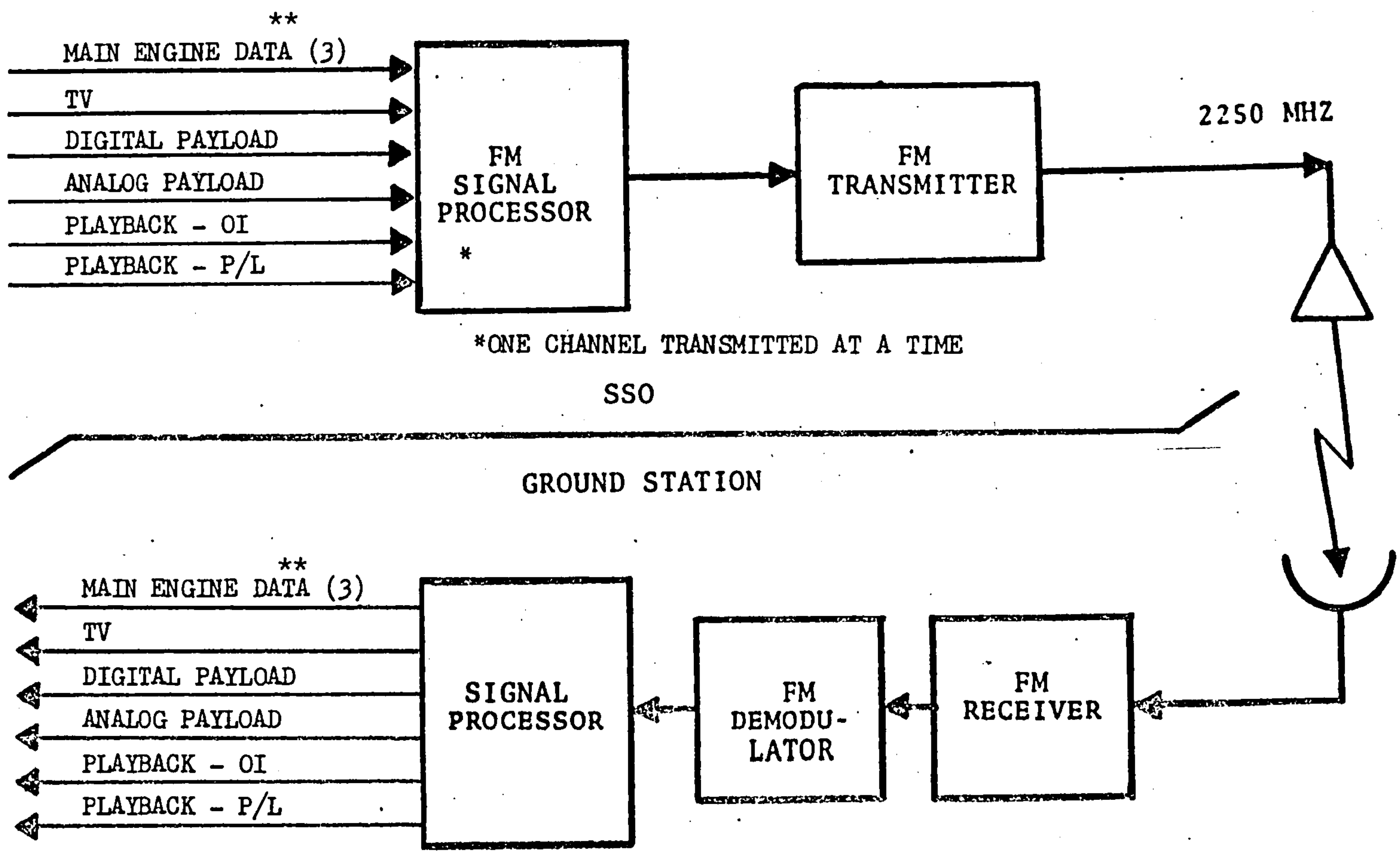


a HIGH DATA RATE/LOW DATA RATE

b SAME EQUIPMENT USED FOR S-BAND AND Ku-BAND RETURN RELAY LINKS

c FRAME SYNC USES TELEMETRY SYNC PATTERN

Figure 5-2.- SSO-to-GSTDN S-band PM direct downlink functional configuration.



**SELECTION TO BE USED FOR ASCENT PHASE

Figure 5-3.- SSO-to-GSTDN/IOS S-band FM directdownlink functional configuration.

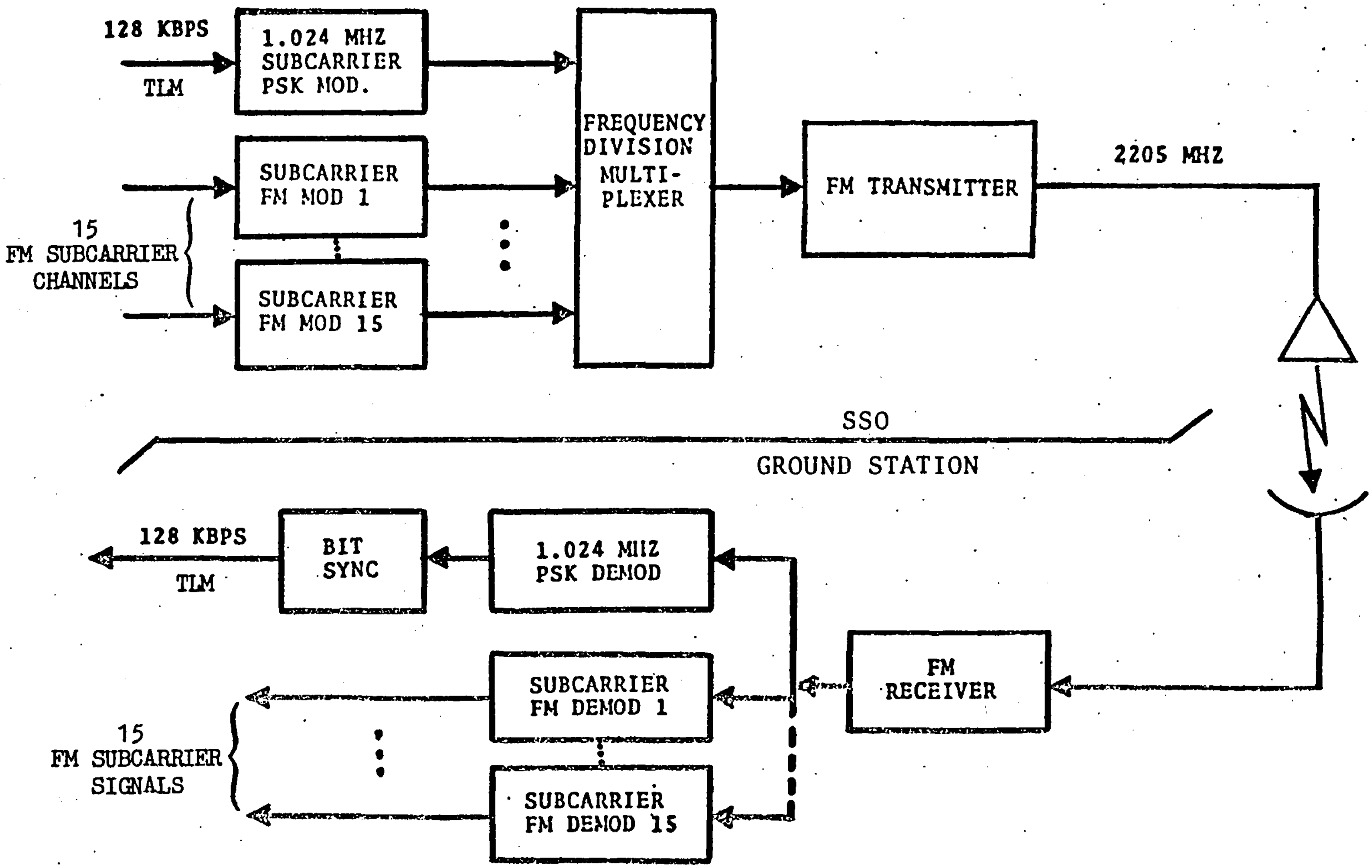


Figure 5-4.- SSO-to-GSTDN S-band FM DFI downlink (2205 MHz) functional configuration.

TABLE 5-I.- GSTDN-TO-SSO S-BAND DIRECT UPLINK INTERFACE CHARACTERISTICS

INFORMATION		PREMODULATION PROCESSING	CARRIER MODULATION		CARRIER FREQUENCY
CHANNEL	RATE or FREQUENCY		RANGING ON	RANGING OFF	
Voice 1 a Voice 2 a Command Synchronization	32/24 kbps b 32/off kbps b 6.4 kbps c 1.6 kbps d	Time-Division-Multiplexing Sync pattern: 76571440_8 Bit rate: 72 r/32 kbps b ±0.001% Bit format: bi-phase-L	PM q β= 1.1 ±10% rad	PSK β=π/2 ±10% rad	2106.406300 MHz or 2041.947900 MHz
Major tone e Minor tone f	500 kHz 100/20/4 kHz 800/160/40/10 Hz g	Subcarrier Phase Modulation Subcxr freq: 1.7 MHz h Major tone: β=0.6±10% rad Minor tone: β=0.6±10% rad	PM β= 1.0 ±10% rad	NA	

GSTDN MIN EIRP		ANTENNA POLARIZATION	SSO MIN G/T j	SSO REQUIRED P_{rec}/N_o, dBHz			
ANT. (m)	dBW			UPLINK MODULATION	CARRIER ACQUISITION k	CARRIER and RANGE CHANNEL TURNAROUND l,q	DATA ACQUISITION m,q
4.3	57 p	RCP	-34.5 dB/K (without preamp)	High rate data with ranging	NA	52.1	61.8
4.3	68.8 i		-28.5 dB/K (with preamp)	Low rate data with ranging	NA	51.1	58.3
9	76			High rate data w/o ranging	NA	49.1 n	58.5
26	83.5			Low rate data w/o ranging	NA	48.1 n	55.0
				Unmodulated	45.0	44.0 o	NA

a Delta-modulated
b High data rate/low data rate
c 2.4 kbps command channel is dummy filled to 2.5 kbps, BCH(127,50) encoded to 6.35 kbps, and dummy filled to 6.4 kbps before multiplexing with the other channels
d 1.2 kbps sync pattern dummy filled to 1.6 kbps
e Continuous during ranging
f 7 minor tones, one at a time, only during major tone phase delay resolution
g The 800, 160, 40, or 10 Hz minor tone is modulated onto the 4 kHz tone for transmission
h Frequency stability 3 parts in 10^{11} (short term)
i Quito GSTDN site
j Based on +3 dB SSO antenna gain
k 90% probable in 6 seconds. Normal uplink acquisition with modulation off
l Carrier in-lock tracking with mean time to lose lock at least 1 hour. Carrier and ranging channel are not turned around when carrier is not in lock
m For 10^{-4} BER
n In the absence of uplink ranging subcarrier, ranging channel noise is turned around
o Ranging channel is not present (i.e., only the carrier is turned around since ranging is not present)
p Buckhorn EIRP = 55.5 dBW
q Changes pending to increase β to 1.25 for on-orbit and landing support and to 1.30 for launch support. Threshold calculations in section 1 already reflect these changes.
r For MIL, PDL, and BDA the data will be convolutionally encoded to 216 kbps during launch phase

TABLE 5-II.- SSO-TO-GSTDN S-BAND PM DIRECT DOWNLINK INTERFACE CHARACTERISTICS

INFORMATION		TIME-DIVISION MULTIPLEXING	CARRIER MODULATION		CARRIER FREQUENCY	
CHANNEL	RATE or FREQUENCY		COHERENT CARRIER	AUX OSC CARRIER	COHERENT CARRIER	AUX OSC CARRIER
Voice 1 a Voice 2 a Telemetry	32/32 kbps b 32/off kbps b 128/64 kbps b	Sync pattern: 76571440_8 c Bit rate: 192/96 kbps b ±0.01% Bit format: bi-phase-L	PM β= 0.55 ±10% rad	PM β= 0.55 ±10% rad	240/221 x rcvd. freq.	2287.5 ±0.001% MHz or 2217.5 ±0.001% MHz
Ranging turn-around d	1.7 MHz e	NA	PM β= 1.0 +20% −10% rad f	NA g		

SSO MIN EIRP h	ANTENNA POLARI-ZATION	GSTDN MIN G/T i		GSTDN REQUIRED P_{rec}/N_0, dBHz l			
		ANT. (m)	dB/K	Downlink Modulation	Carrier Acquisi-tion m	Ranging and /or Doppler Tracking n	Data Acquisi-tion r
1 dbW (low power mode) 16.7 dBW (high power mode)	RCP	4.3 4.3 9 12 26	9.8 j 9.9 k 22.0 21.2 31.2	Coherent carrier: Data (HDR/LDR) + Ranging channel	63.5	53.5 o	HDR: 70.7 LDR: 67.7
				Auxiliary oscil-lator carrier: Data (HDR/LDR)	61.2	51.2 p	HDR: 68.3 LDR: 65.3
				Coherent carrier: Unmodulated	59.8	49.8 q	NA

a Delta-modulated
b High data rate (HDR)/low data rate (LDR)
c TDM frame sync uses telemetry sync pattern
d Bandpass-filtered SSO receiver noise plus, when transmitted from GSTDN, the tone-modulated 1.7 MHz ranging subcarrier (table 4-IV)
e Center frequency of the turnaround bandpass filter
f For high SNR turnaround ranging subcarrier. For turnaround noise alone, the carrier rms phase deviation is approximately 0.7 radians
g Turnaround channel is not transmitted in the auxiliary oscillator carrier mode.
h Based on +3 dB SSO antenna gain
i Nominal G/T at $\geq 3^{\circ}$ above land mask. Below 3°, G/T decreases as described in STDN Link Analysis Handbook, Volume 3: STDN S-Band Antenna Gains, EIRPs, and Antenna Noise Temperatures. Site-to-site variations are included in this document
j BUC, PDL, TUL systems
k QUI dual 4.3 meter system. Operationally, the 40-ft system at QUI (21.2 dB/k) will be used for downlink.
l Does not include allowance for GSTDN antenna diversity combining loss
m 90% probable in 3 seconds
n Carrier in-lock tracking with required Doppler measurement and ranging performance
o Two-way Doppler and ranging (when present on the uplink)
p One-way Doppler
q Two-way Doppler only
r For 10^{-4} BER

TABLE 5-III.- SSO-TO-GSTDN S-BAND 2250-MHz FM OI DOWNLINK INTERFACE CHARACTERISTICS

INFORMATION		SUBCARRIER FREQUENCY and MODULATION	CARRIER PEAK FREQUENCY DEVIATION
CHANNEL a	BIT RATE or BASEBAND WIDTH		
Main engine 1 b	60 kbps ± 0.01%	576 kHz ±0.01% PSK	635 kHz ±15%
Main engine 2 b	60 kbps ± 0.01%	768 kHz ±0.01% PSK	635 kHz ±15%
Main engine 3 b	60 kbps ± 0.01%	1024 kHz ±0.01% PSK	635 kHz ±15%
Television	4.5 MHz	NA	4.5 MHz ±15%
Payload - digital c	200 bps to 5 Mbps ±0.01%	TBD	2 MHz ±15%
Payload - analog	300 Hz to 4 MHz	NA	2 MHz ±15%
Playback - OI b	60-1024 kbps ±0.5% d	NA	635 kHz ±15%
Playback - P/L b	25.5-1024 kbps ±0.5% d	NA	635 kHz ±15%

CARRIER FREQUENCY	SSO MIN EIRP f	ANTENNA POLARIZATION	GSTDN MIN G/T h		GSTDN REQUIRED P_{rec}/N_o k	
			ANT. (m)	dB/K	CHANNELS	dBHz
2250 MHz ±450 kHz e	4.1 dBW g	RCP	4.3	9.8 i	Main engine (all together)	76.8 l
			4.3	9.9 j	Television	83.5 m
			9	22.0	Payload (5 Mbps digital)	84.8 n
			12	21.2	Payload (analog)	TBD o
			26	31.2	Playback (1024 kbps)	77.0 p

a One channel at a time, except all three main engine channels come together
b Bi-phase-L signal format
c NRZ-L format, 200 bps - 5 Mbps. Bi-phase-L format, 200 bps to 2 Mbps
d Channels recorded and playback bit rates will be established mission-by-mission.
e Maximum drift rate 40 kHz per month
f Based on SSO hemi antenna gain of +1 dB
g 1.6 dBW for STS-1 through STS-4; for these missions, the 2205-MHz FM DFI downlink (see table 5-IV) is present and is diplexed with the 2250-MHz downlink, resulting in a higher circuit loss and lower EIRP for the 2250-MHz link.
h Nominal G/T at $>3^o$ above land mask. Below 3^o, G/T decreases as described in STDN Link Analysis Handbook, Volume 3: STDN S-Band Antenna Gains, EIRPs, and Antenna Noise Temperatures. Site-to-site variations are included in this document
i BUC, PDL, TUL systems
j QUI dual 4.3 meter system. Operationally, the 40-ft system at QUI (21.2 dB/k) will be used for downli
k Does not include allowance for GSTDN antenna diversity combining loss
l Based on 10 dB min SNR in 4.8 MHz predetection noise bandwidth
m Based on 30 dB min SNR (P-P/rms) in 3 MHz postdetection noise bandwidth (using 14.5 MHz predetection noise bandwidth)
n Based on 14.8 dB min E_b/N_o for 10^{-4} BER (using 14.5 MHz predetection noise bandwidth)
o Based on more stringent requirement of specified min SNR (rms/rms) in specified postdetection noise bandwidth or 10 dB min SNR in appropriate available predetection noise bandwidth. Actual values depend on individual payload signal characteristics and performance requirements
p Based on 13.9 dB min E_b/N_o for 10^{-4} BER (using 4.8 MHz predetection noise bandwidth)

TABLE 5-IV.- SSO-TO-GSTDN 2205-MHz FM DFI DOWNLINK INTERFACE CHARACTERISTICS

Carrier frequency	SSO min. EIRP[a] (dBW)	Antenna polarization	GSTDN min. G/T[b]		GSTDN required P_{rec}/N_0 (dBHz)
			Antenna size (m)	dB/K	
2205 MHz ±0.003%	-3.2	RCP	4.3	9.8 (c)	76.8[e] (74.9)
			4.3	9.9 (d)	
			9	22.0	
			12	21.2	
			26	31.2	
			18.3	22.9 (g)	

[a]Based on SSO hemi antenna gain of -2 dB

[b]Nominal G/T at >3° above land mask. Below 3°, G/T decreases as described in reference 6. Site-to-site variations are included in this document.

[c]BUC, PDL, and TUL systems

[d]QUI dual 4.3 meter system. Operationally, the 40-ft system at QUI (21.2 dB/k) may be used for downlink.

[e]Based on 10 dB minimum SNR in 4.8 MHz predetection noise bandwidth

[f]Based on 10 dB minimum SNR in 3.1 MHz predetection bandwidth (IOS only)

[g]IOS system

6. SYSTEM DESCRIPTION: SHUTTLE ORBITER UHF RF VOICE LINK WITH GSTDN GROUND STATIONS

In addition to the operational S-band links, an SSO UHF voice link is provided to transmit and receive one real-time simplex analog voice channel to GSTDN ground stations. UHF voice is required during ascent and descent phases and serves as a backup to S-band voice during orbital phases. The characteristics of this link are described in the following paragraphs.

6.1 Link Functional Description

The link functions in a simplex mode (i.e., push-to-talk, release-to-listen). The ground station is required to transmit and the SSO UHF transceiver is required to receive an unmodulated continuous-wave carrier, or an analog-voice amplitude-modulated (AM) carrier. Analog voice amplitude modulates the carrier (259.7 MHz or 296.8 MHz). An envelope detector is used to recover the analog voice. Figure 6-1 shows the uplink functional interface configuration.

The UHF voice downlink may function in any one of the three simplex modes identified in table 6-I when using the SSO-unique UHF transceiver; however, only the 259.7-MHz and 296.8-MHz carrier frequencies are supported by the GSTDN.* The SSO transceiver is required to transmit and the GSTDN is required to receive an unmodulated continuous-wave carrier, or an analog-voice amplitude-modulated carrier. The analog voice is pre-processed and then amplitude-modulates the carrier. On the ground, an envelope detector is used to recover the analog voice. Figure 6-2 shows the downlink functional interface configuration.

6.2 RF Characteristics

Amplitude modulation is employed with a modulation index equal to 90 ± 10 percent for both the SSO-unique and the GSTDN ground station tranceivers. The center frequency of the GSTDN or SSO transmitter will not deviate more than ±.003 percent from the assigned center frequency (296.8 MHz or 259.7 MHz). The interface parameters associated with system configurations and signal designs are summarized by tables 6-II and 6-III.

*The third mode uses a 243-MHz carrier (the international distress channel) which is not supported by GSTDN.

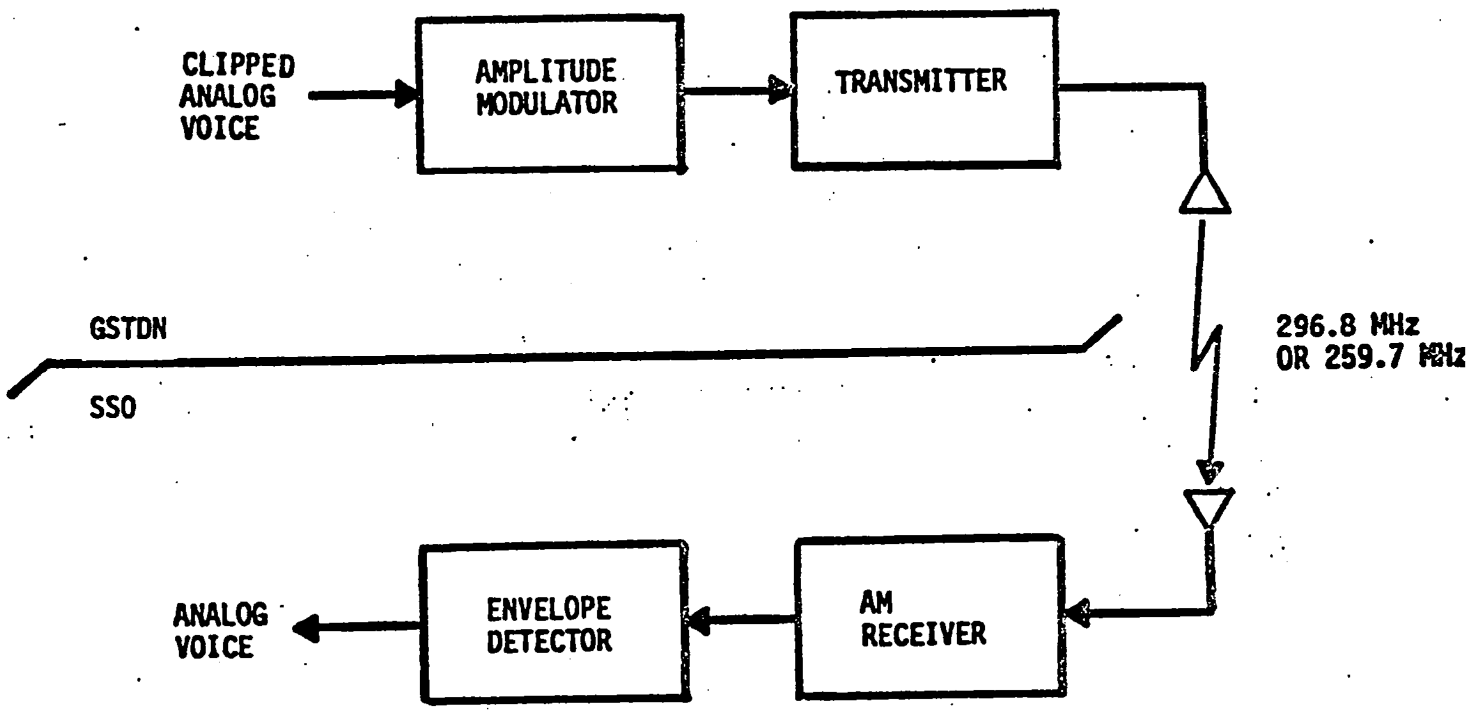


Figure 6-1.- Functional interface configuration
for the GSTDN-to-SSO UHF link.

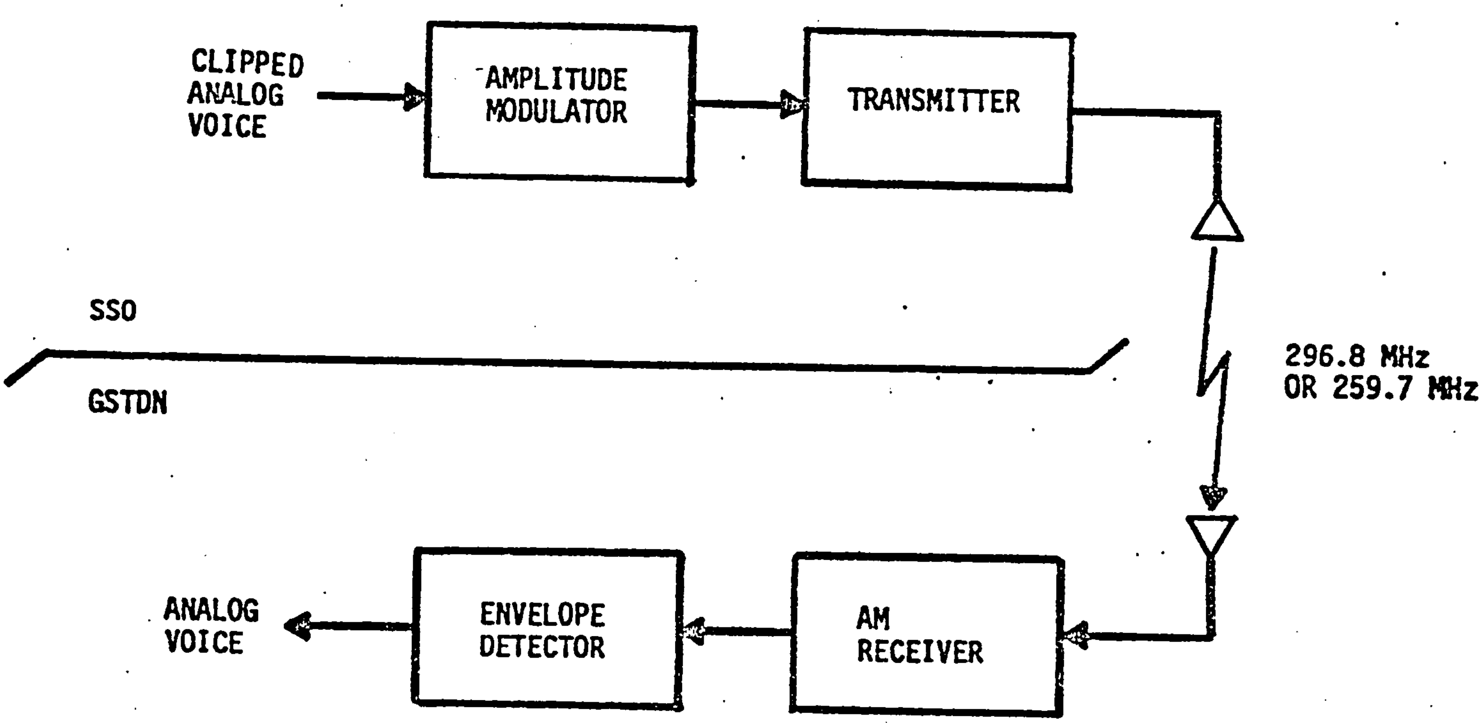


Figure 6-2.- Functional interface configuration
for the SSO-to-GSTDN UHF link.

TABLE 6-I.- SSO-UNIQUE UHF TRANSCEIVER OPERATION MODES

Transmit frequency	Mode		
	Simplex	Simplex plus guard receive*	Guard transmit/receive*
296.8 MHz	Transmit and receive on 296.8 MHz	Transmit and receive 296.8 MHz simultaneous receive on 243 MHz	Transmit and receive on 243 MHz
259.7 MHz	Transmit and receive on 259.7 MHz	Transmit and receive on 259.7 MHz, simultaneous receive on 243 MHz	Transmit and receive on 243 MHz

*The 243 MHz frequency is the international distress channel and is not supported by GSTDN.

TABLE 6-II.- SSO-TO-GSTDN UHF VOICE DOWNLINK CHARACTERISTICS

Information		RF Carrier			SSO Min. EIRP	GSTDN G/T		GSTDN Required P_{rec}/N_o [c]
Channel	Frequency Response	Modulation	Mod. Index, %	Frequency				
Voice[a]	300 to 3000 Hz	Amplitude	90 ±10	259.7 MHz ±0.003% or 296.8 MHz ±0.003%	7.1 dBW	TELTRAC 18-element	-8.3 dB/K	59.3 dBHz
						TELTRAC 32-element	-5.6 dB/K	
						Quad Helix (8417 Mount)	-9.3 dB/K	
						Discone	-31.4 dB/K [b]	
						Discone (DFRC)	-33.2 dB/K [b]	
						3.7 m (DFRC)	-18.7 dB/K	

a Rms-to-peak ratio 0.514 (12 dB clipping)

b Near horizon

c Total-received-power-to-noise spectral density ratio to achieve a postdetection signal-to-noise ratio (rms/rms) of 16 dB (90% WI)

TABLE 6-III.- GSTDN-TO-SSO UHF VOICE UPLINK CHARACTERISTICS

Information		RF Carrier			GSTDN Min. EIRP		SSO G/T	SSO Required P_{rec}/N_o [c]
Channel	Frequency Response	Modulation	Mod. Index, %	Frequency				
Voice[a]	300 to 2800 Hz	Amplitude	90 ±10	259.7 MHz ±0.003% or 296.8 MHz ±0.003%	TELTRAC 18-element	36.4 dBW	-37.3 dB/K	65.7 dBHz
					TELTRAC 32-element	38.2 dBW		
					Quad Helix (8417 Mount)	35.4 dBW		
					Discone	20.9 dBW [b]		
					Discone (DFRC)	18.7 dBW		
					3.7 m (DFRC)	32.5 dBW		

a Rms-to-peak ratio 0.3 (4.5 dB clipping)

b Near horizon

c Total received power-to-noise spectral density ratio to achieve a 0 dB margin based on a postdetection signal-to-noise ratio (rms/rms) of 16 dB (90% WI)

7. REFERENCES

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